Neuropsychologia, Vol. 29, No. 10, pp. 1007–1018, 1991.
Printed in Great Britain.

0028-3932/91 $3.00+0.00

INDIRECT MEASURES OF MEMORY IN A DURATION-JUDGEMENT TASK ARE NORMAL IN AMNESIC PATIENTS

KEN A. PALLER,*† ANDREW R. MAYES,* MARK MCDERMOTT,* ALAN D. PICKERING‡ and PETER R. MEUDELL*

*Department of Psychology, University of Manchester, Manchester, U.K.; and ‡Department of Psychology, St George's Hospital Medical School, London, U.K.

(*Received* 1 *October* 1990; *accepted* 10 *April* 1991)

Abstract—Nine amnesic patients of mixed aetiology were studied in a duration-judgement task that allowed three measures of memory to be obtained. On each trial of the task, subjects attempted to read a briefly flashed word and to estimate the duration of the flash. Both word identification and duration estimation differed as a function of prior study. Words that were previously studied were identified more often and were estimated to have been flashed for a longer duration than were words not previously studied. These priming effects were found in young subjects in Experiment 1 and in amnesic patients and age-matched control subjects in Experiment 2. Priming effects were normal in the amnesic patients, whereas these patients were severely impaired at recognizing the same words. Previous results have also shown that amnesic patients can perform normally on certain memory tests, including priming of word identification. These results show that priming of duration judgements can also be included in the category of indirect measures of memory that are spared in amnesia.

INTRODUCTION

ALTHOUGH memory has traditionally been assessed by recall or recognition tests, memory can also be tested indirectly by using other performance measures that can vary as a function of prior experience. For example, many experiments have shown that one presentation of a word can increase the probability that it will later be identified when presented in a perceptually difficult situation (e.g. [2, 8]). Such a situation can be produced by pattern masking, when a word is flashed for a short duration (e.g. 35 msec) followed immediately by another pattern (e.g. a row of ampersands). This improved word identification is one example of a *repetition priming effect*, and as such can theoretically be distinguished from recall and recognition. One important characteristic of priming is that during the test, subjects are not asked about their memories directly. These two types of test, indirect memory tests and direct memory tests, are affected differentially by experimental variables such as the level of processing during encoding (e.g. [5, 9]). Implications of such empirical dissociations for theories of memory, however, are controversial (see [14, 15] for reviews).

Neuropsychological experiments have shown that priming effects can occur in amnesic patients who are impaired on standard recall and recognition tests for the same material, and further, that these priming effects can be normal (see [16, 18]). Finding normal levels of

†Address correspondence to: Ken Paller, Department of Cognitive Science, University of California at San Diego, La Jolla, CA 92093–0515, U.S.A.

priming is critical because subnormal effects would be open to the criticism that the priming measure was merely more sensitive to memory than the direct memory measure. Further, identifying a memory function that is normal in amnesia helps to place limits on characterizations of the functional deficit of amnesia. On the other hand, impaired priming in amnesic patients could arise trivially if priming performance was normally mediated by conscious recollection, so it is important that these paradigms minimize this possibility. Although it is difficult to show conclusively that a priming effect in a subject with normal memory does not depend on the conscious recollection of prior episodes, preserved priming effects in amnesia are consistent with this idea. Preserved priming effects have previously been reported using measures such as word identification [1], word completion (e.g. [6]), homophone spelling [12], free association (e.g. [17]), and lexical decision (e.g. [4]).

One type of priming that has not been assessed in amnesia uses subjective reports of the duration of visual stimuli. This priming effect may correspond to the common experience that the speed with which a foreign language is spoken appears to be very fast until the language becomes well-learned. In the priming paradigm developed by WITHERSPOON and ALLAN [20], subjects were shown masked words and asked to identify each word and then to estimate on a four-point scale how quickly it had been flashed. Prior study increased both the accuracy of identification and the magnitude of duration judgements. In effect, subjects reported that the studied words remained on the screen longer than did words that had not been studied. JACOBY and colleagues [10, 11] have suggested that this type of priming effect arises from *relative perceptual fluency* (i.e. increased efficiency in processing a previously studied word), which leads subjects to make an erroneous *automatic attribution* that the fluency was due to the nature of the stimulus rather than prior study. Accordingly, evidence for the preservation of duration-judgement priming in amnesic patients could imply that both hypothetical processes, relative perceptual fluency and the attribution process, were intact. Previous studies of priming in amnesia have not used tasks likely to depend on an automatic attribution process. A demonstration that the attribution process is intact in amnesia could prove important for understanding the recognition deficit, since one of the processes that contributes to recognition may be an analogous attribution process leading to familiarity [10, 11].

Using a paradigm similar to that used by WITHERSPOON and ALLAN [20], we investigated priming in patients with organic amnesia due to several neurological causes. The paradigm allowed priming of both word identification and temporal estimation to be assessed. Conscious recollection of studied words may not have an important influence on these measures, given the speed with which responses are made and the lack of an obvious connection between making the response and recollection. Young subjects were studied in Experiment 1; amnesic patients and age-matched control subjects were studied in Experiment 2.

EXPERIMENT 1

An initial goal was to replicate the priming effects on word identification and duration judgements [20]. In this way, potential problems that amnesic patients might encounter in learning the various performance requirements could be anticipated. We also included a between-subjects manipulation of exposure duration. Given that words must remain on the screen for an abnormally long time in order for them to be identified by some amnesic patients, it is important to determine whether duration-judgement priming differs when longer durations are used. To make this determination, one group of subjects was shown words at a duration near the threshold level for identification (as in [20]) and another group of subjects was shown words at a longer duration such that all words could be identified.

Method

Design. The two groups of subjects were designated the near-threshold group and the above-threshold group. In addition, there were two within-subjects variables: Repetition Priming (primed or unprimed) and Duration of Exposure (long or short). The two durations were required for the duration-judgement task. Dependent variables were word identification, duration estimation and recognition. Data were analysed using analyses of variance (ANOVAs) with repeated measures and the 0.05 level for significance.

Subjects. Sixteen undergraduates from the Department of Psychology at the University of Manchester served as subjects in the experiment. Subjects were between 18 and 29 years of age (mean = 20.3). Half of the subjects were men. Each subject was randomly assigned to either the near-threshold group or the above-threshold group.

Materials. A word pool of 194 five-letter nouns with a frequency of usage less than 21 occurrences per million [3] were selected. For each subject, the words were randomly divided into five lists: 40 critical words, 40 novel words, 80 recognition foils, 20 study fillers and 14 practice words. Words were presented in upper-case letters 6 mm high and viewed from a distance of approximately 75 cm.

Procedure. Subjects were tested individually in a session that lasted approximately 45 min. Instructions stressed that the main objective of the experiment was to investigate speeded reading ability and that the subject would be asked to read aloud words presented at different exposure durations on a video monitor. Actually, words that were studied in Phase 1 appeared again in a priming test (Phase 4) approximately 20 min later as well as in a recognition test (Phase 5) approximately 25 min later. Specific instructions preceded each phase.

Phase 1: Study. A list of 60 words was presented at a rate of one word per second. The subject was instructed to read each word aloud rapidly and accurately. The study list began and ended with five study fillers and included an additional 10 study fillers and 40 critical words randomly intermixed.

Phase 2: Training for the duration-judgement task. In this phase the subject was trained to use an arbitrary numerical code for estimating temporal intervals. Instead of words, the same letter string ("ZZZZZ") was used on every trial. The letter string was preceded and followed by the mask stimulus ("&&&&&"), the duration of which was 500 msec in both cases. The duration of the letter string was thus identical to the time from the onset of the letter string until the onset of the mask, otherwise known as the Stimulus Onset Asynchrony or SOA. The letter string was presented at one of four possible durations: 40, 60, 80 or 100 msec for the near-threshold group; 160, 180, 200 or 220 msec for the above-threshold group. The subject was asked to categorize the duration of the letter string by calling aloud the number *1*, *2*, *3* or *4*. This four-point scale was explained using demonstration flashes at each duration and a card was displayed to provide the information that *1* denoted that briefest duration and *4* denoted the longest duration. The experimenter keyed the subject's response into the computer. Each duration occurred in a pseudorandom order five times in each 20-trial block. Several 20-trial blocks, each followed by feedback on performance, were run until the subject was consistently performing above chance (25% correct), but levels of accuracy higher than 75% were seldom reached.

Phase 3: Practice. In this phase, subjects were asked to read each word presented and to estimate its duration using the four-point scale. Subjects were instructed to attempt word identification first and then, even if the word could not be identified, to give a duration estimate. Fourteen practice words were used, masked as in Phase 2. The durations differed from those used in Phase 2, but the subject was not informed of this fact. Only durations corresponding to ratings *1* and *3* were used (40 and 80 msec for the near-threshold group, 160 and 200 msec for the above-threshold group); these will be denoted *SOA-1* and *SOA-3*, respectively. Word identification and duration estimation were monitored by the experimenter.

Phase 4: Priming test. Instructions for this phase were identical to those for Phase 3. A total of 80 words were presented for identification and duration estimation; 40 of the words had been displayed during Phase 1 (critical words) and 40 of the words had not previously been presented (novel words). These words thus formed the two conditions of *primed words* and *unprimed words*, respectively. For the primed words as well as for the unprimed words, half were presented at SOA-1 and half were presented at SOA-3. Words were presented in a different random order for each subject.

Phase 5: Recognition test. The final phase was a forced-choice recognition test. On each of 40 trials, one critical word and two recognition foils were displayed in a row in a random order. The subject was instructed to try to select the word that had been encountered previously during the experimental session. The words remained on the screen until the subject made a selection, whereupon the experimenter entered the response into the computer. Recognition scores were near ceiling and will not be reported.

Results

Identification. As expected, identification was much better in the above-threshold group than in the near-threshold group. In fact, all words were identified correctly in the above-threshold group. In the near-threshold group there were clear priming effects. For SOA-1, the proportion of words identified rose from 0.71 to 0.91 as a result of prior study; for SOA-3, the proportion rose from 0.91 to 0.97. For the near-threshold group, a two-way ANOVA (Priming × Duration) showed that the priming effect was significant [$F(1, 7) = 12.6$, $P = 0.01$] and that identification was better at the long duration [$F(1, 7) = 30.1$, $P = 0.001$]. The Priming by Duration interaction, however, was nonsignificant.

Table 1. Mean duration estimates in Experiment 1

	Group			
	Near-threshold		Above-threshold	
Condition	SOA-1	SOA-3	SOA-1	SOA-3
Primed	2.34	2.83	2.18	2.48
Unprimed	2.14	2.64	2.09	2.44
Difference	0.20	0.19	0.09	0.04

Duration estimates. Mean duration estimates for both groups are shown in Table 1 as a function of presentation duration and priming. The overall priming effect, as analysed in a three-way ANOVA (Priming × Duration × Group), was significant [$F(1, 14) = 8.9$, $P = 0.01$]. There was a significant main effect of presentation duration [$F(1, 14) = 33.1$, $P = 0.001$], as larger estimates were given for the longer SOAs. Priming effects tended to be larger in the near-threshold group, although the Priming by Group interaction and all other effects in the ANOVA were nonsignificant.

Discussion

The results replicated the findings of WITHERSPOON and ALLAN [20] in showing that one prior presentation of a word can influence performance measures in the duration-judgement task. The usual repetition priming effect was found for word identification when identification scores were below ceiling. Also, repeated words were judged to have remained on the screen longer than unrepeated words exposed for objectively the same duration. Near-threshold durations (as used in [20]) were apparently not necessary for priming of duration estimations; both groups of subjects showed significant priming effects.

The design of the duration-judgement task called for some deception, as subjects were led to believe that there were four different durations, but only two durations were actually used. When subjects were debriefed, however, some reported the suspicion that there were only two durations. In any event, given that duration estimates were larger for SOA-3 than for SOA-1, it is clear that the actual presentation durations influenced the estimates. But duration was not the sole influence; repetition had a reliable influence as well. According to an attributional model of memory [11], subjects can experience effects of repetition but attribute them to duration instead, thus making a misattribution, as will be discussed further below.

EXPERIMENT 2

In Experiment 2 we used the duration-judgement task to investigate priming in amnesia. At the outset, it was unclear whether the performance requirements of the procedure would prove too taxing on the patient's memory functions. Nevertheless, the patients were able to advance successfully through the five stages of the paradigm. The results from Experiment 1 showed that duration estimations can function as indirect measures of memory, even when durations above the identification threshold are used. Because above-threshold durations led to ceiling effects in identification, the tactic in Experiment 2 was to approximate near-threshold durations so that both priming of identification and priming of duration estimations would be possible. Whereas a 40 msec SOA sufficed for the near-threshold condition in Experiment 1, the ability to read briefly flashed words was abnormal in some of the amnesic patients, perhaps due to lower acuity, advanced age, or neuropathology. We therefore included a threshold-setting procedure so that SOAs could be set individually for each subject.

Method

Design and materials. Experimental Group (amnesic or control) was the between-subjects variable and there were two within-subjects variables: Repetition Priming (primed or unprimed) and Duration of Exposure (long or short) Dependent variables and analyses were the same as described for Experiment 1, as were the materials, except that an additional list of 100 five-letter nouns was generated for determining appropriate SOAs.

Subjects. The test was given to a group of amnesic patients ($N=9$) and a group of control subjects who were matched to the patients on age, intelligence and socioeconomic background ($N=9$). Each group included eight men and one woman. The patients' memory dysfunctions were due to Korsakoff's syndrome, ruptured and/or operated anterior communicating artery aneurysm, cerebrovascular accident, viral encephalitis, meningitis or closed-head injury. Test scores from each of the individual patients are listed in Table 2. The mean age was

Table 2. Results from standardized neuropsychological tests

Patient	Aetiology	Age	F-IQ	V-IQ	P-IQ	NART	WRT-W	WRT-F	MQ
B.D.	K	53	125	132	113	124	45	36	97
K.H.	K	54	104	103	104	102	37	39	91
D.F.	ACAA	22	90	90	91	105	31	36	70
A.B.	ACAA	37	100	103	96	112	30	28	77
J.S.	CVA	59	104	99	109	107	26	35	63
J.E.	VE	22	92	96	89	99	42	39	66
R.S.	VE	41	89	101	74	106	33	33	81
N.M.	M	38	96	93	101	96	26	32	80
B.B.	CHI	38	81	82	82	91	44	29	70

Note. Patients' memory dysfunctions were classified as due to Korsakoff's syndrome (K), ruptured and/or operated anterior communicating artery aneurysm (ACAA), cerebrovascular accident (CVA), viral encephalitis (VE), meningitis (M) or closed-head injury (CHI). Scores are given for the full-scale (FIQ), verbal (VIQ), and performance (PIQ) intelligence quotients of the WAIS; the National Adult Reading test (NART); the Warrington Recognition Memory test for words (WRT-W) and for faces (WRT-F); and the Wechsler Memory Quotient (MQ).

40.4 years for the amnesic group and 39.9 years for the control group [$F(1, 16)<1$]. The Wechsler Adult Intelligence Scale was given to each patient to obtain general estimates of intelligence. Mean scores for full-scale, verbal and performance IQ were 98 ($SE=4$), 100 ($SE=5$) and 95 ($SE=4$), respectively. An estimate of premorbid full-scale IQ, derived from the National Adult Reading test (NART), was 105 ($SE=3$). The mean IQ score for the control group, estimated using four subtests (similarities, vocabulary, picture completion and block design), was 111 ($SE=3$). Although full-scale IQ was significantly lower in the amnesic group than in the control group [$F(1, 16)=6.4$, $P=0.022$], the NART score in the amnesic group did not differ significantly from the full-scale IQ score in the control group [$F(1, 16)=2.1$]. Each patient had some degree of amnesia, but patients were selected so that severity varied considerably in order to ascertain whether there was an association between degree of memory deficit and amount of priming. Even the least severe amnesic cases in the sample showed impaired scores on our special-purpose memory tests. Scores from several standardized memory tests were as follows. The mean score in the amnesic group on the Warrington Recognition Memory test for words was 35 ($SE=2$). The maximum score on this test is 50 whereas guessing alone would tend to yield a score of 25. A score of 35 falls below the fifth percentile of age-corrected norms. The mean score in the control group was 47 ($SE=1$), which was significantly greater than the mean in the amnesic group [$F(1, 16)=23.4$, $P<0.001$]. In addition, mean scores in the amnesic group were 34 ($SE=1$) on the Warrington Recognition Memory test for faces and 77.2 ($SE=4$) on the Memory Quotient of the Wechsler Memory Scale.

Procedure. The procedure was similar to that of Experiment 1, with the following modifications. First, an additional phase was included at the beginning of the experiment to determine an appropriate SOA-1 for each subject. The subject was asked simply to identify words that were masked as in Experiment 1. The SOA was first adjusted so that the words were easy to read (i.e. 200 msec or greater), and then it was reduced until the words could not be identified accurately. In this way, the experimenter selected an SOA that led to near-threshold word identification (i.e. the lowest SOA that still led to correct identification for more than about 20% of the words).

The following minor procedural changes were also made. Phase 1 was run twice to ensure that the words were well encoded. In Phase 2, a value for the duration separation was selected by the experimenter such that the subject could estimate durations with an accuracy of at least 50% correct. The SOA-1 determined earlier was used as the shortest duration. In most subjects, 20 msec (the screen refresh period) functioned as the difference between the four durations (e.g. 40, 60, 80 and 100 msec), but in five of the amnesic patients and one of the control subjects, a larger separation between durations was used. In addition, subjects were given trial-by-trial feedback about their duration estimates to facilitate the training procedure. This feedback was a message that appeared at the top of the screen each time the experimenter keyed in the subject's response. If the subject gave the correct estimate for a particular presentation duration the word *CORRECT* appeared at the top of the screen. Otherwise the word *WRONG* appeared along with the correct response. Finally, rather than randomizing the word-to-condition assignments for each subject, the same randomization scheme was used for all subjects.

Results

SOA settings. Determining the lowest durations feasible for reading words and making accurate duration judgements led to individualized settings for SOA-1 and SOA-3. In all cases, settings were made in 20 msec increments. In the amnesic group ($N=9$), the mean settings were 127 msec ($SE=44$) for SOA-1 and 248 msec ($SE=83$) for SOA-3. In the control group ($N=9$), the mean settings were 49 msec ($SE=5$) for SOA-1 and 93 msec ($SE=9$) for SOA-3. A separate analysis was also done for amnesic patients with lower settings ($n=6$) and a subgroup of control subjects selected such that SOA settings were matched ($n=6$). In the amnesic subgroup, the mean settings were 57 msec ($SE=8$) for SOA-1 and 110 msec ($SE=16$) for SOA-3. In the control subgroup, the mean settings were 53 msec ($SE=7$) for SOA-1 and 100 msec ($SE=13$) for SOA-3. SOA settings were analysed in a two-way ANOVA (Group × Duration). For the subgroups, settings were not significantly different [Group main effect $F(1, 10)<1$, Group by Duration interaction $F(1, 10)<1$]. For the full groups, the trends towards group differences were marginally nonsignificant [Group main effect $F(1, 16)=3.5$, $P=0.081$, Group by Duration interaction $F(1, 16)=3.8$, $P=0.069$].

Identification. Mean scores for word identification are shown in Fig. 1 for the amnesic and control groups collapsed across the two durations. In both groups, words that were primed (i.e. the repeated critical words) were identified more often than were unprimed words (i.e. nonrepeated novel words). The three-way ANOVA (Priming × Group × Duration) showed a significant Priming effect [$F(1, 16)=58.9$, $P=0.001$] as well as a nonsignificant Priming by Group interaction [$F(1, 16)=1.23$], indicating that the priming effect did not differ between the two groups.

Identification scores were much better for the long duration than for the short duration, as shown in Table 3 [$F(1, 16)=45.5$, $P=0.001$]. Perhaps because identification at SOA-3 was near ceiling levels, priming effects at SOA-3 were smaller than those at SOA-1 [$F(1, 16)=29.4$, $P=0.001$]. None of the other effects were significant, except the Priming by Group by Duration interaction [$F(1, 16)=4.6$, $P=0.047$], related to the fact that unprimed words shown at SOA-3 were identified more often in the control group than in the amnesic group.

Given that SOAs were considerably greater in some of the amnesic patients, a further

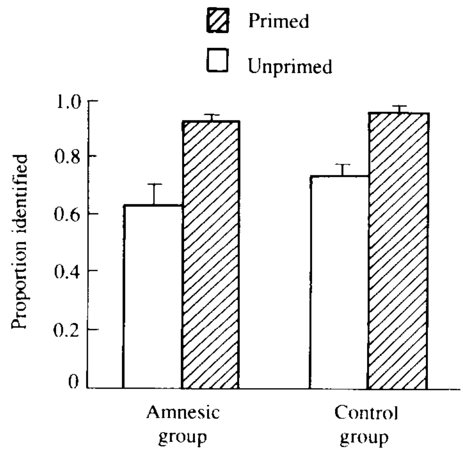

Fig. 1. Identification results from Experiment 2, with error bars showing the standard error of the mean.

Table 3. Mean proportion of words correctly identified in Experiment 2

	Group			
	Amnesic		Control	
Condition	SOA-1	SOA-3	SOA-1	SOA-3
Primed	0.89	0.97	0.94	0.96
Unprimed	0.54	0.72	0.60	0.86
Difference	0.35	0.25	0.34	0.10

analysis was run limited to the six amnesic patients who were able to be run with shorter SOAs and six control subjects with comparable SOAs. Results paralleled those from the full sample, as there was priming for amnesics (an increment in identification proportion from 0.73 to 0.94) and for controls (an increment in identification proportion from 0.71 to 0.94). As before, main effects were found for Priming [$F(1, 10) = 43.7$, $P = 0.001$] and for Duration [$F(1, 10) = 36.7$, $P = 0.001$], and there was a significant Priming by Duration interaction [$F(1, 10) = 16.5$, $P = 0.002$]. However, the Priming by Group by Duration interaction, which had been significant with the full groups, was nonsignificant in this analysis [$F(1, 10) = 2.4$], indicating that unprimed words shown at SOA-3 were no longer identified more often by controls than by amnesics. Further support for the lack of group effects was also provided, as the Priming by Group interaction was nonsignificant [$F(1, 10) < 1$].

Duration estimates. Mean duration estimates are shown in Fig. 2 for the amnesic and control groups collapsed across the two durations. Words that were primed elicited higher ratings than did unprimed words, and the size of this effect did not differ between the two groups. Results from the three-way ANOVA (Priming × Group × Duration) supported this characterization, as there was a significant Priming effect [$F(1, 16) = 30.4$, $P = 0.001$] and a nonsignificant Priming by Group interaction [$F(1, 16) < 1$].

Again, given that different durations were used in the two groups, an additional analysis

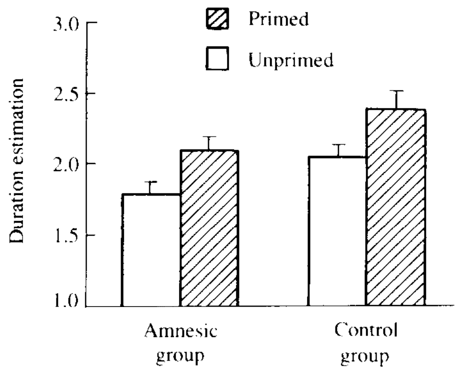

Fig. 2. Duration estimation results from Experiment 2, with error bars showing the standard error of the mean.

was restricted to six subjects matched for duration. Results paralleled those from the full sample, as both subgroups showed similar priming effects (a primed unprimed difference of 0.38 in the amnesic subgroup and 0.33 in the control subgroup). Accordingly, the Priming effect was significant [F (1, 10) = 20.0, P = 0.005] and the Priming by Group interaction was nonsignificant [F (1, 10) < 1].

Duration estimates averaged as a function of SOA are shown in Table 4. Ratings were clearly higher for the long SOA than for the short SOA, [F (1, 16) = 141.8, P = 0.001]. For SOA-3, however, estimates from the amnesic group were lower than those from the control group, as reflected in the Group by Duration interaction [F (1, 16) = 38.4, P = 0.001]. Indeed, several of the patients tended to use only the 1 and 2 ratings. Nevertheless, the priming effect did not differ between the groups and no other effects approached significance.

Table 4. Mean duration estimates in Experiment 2

	Group			
	Amnesic		Control	
Condition	SOA-1	SOA-3	SOA-1	SOA-3
Primed	1.94	2.23	1.92	2.86
Unprimed	1.63	1.95	1.54	2.54
Difference	0.31	0.28	0.38	0.32

The lower sensitivity to SOA differences in the amnesic group can be quantified by subtracting the mean estimate for unprimed words at SOA-1 from the mean estimate for unprimed words at SOA-3. This difference in the amnesic group was about one-third as large as that in the control group (0.32 and 1.00, respectively). A correlational analysis was conducted to determine whether subjects with lower sensitivity to SOA differences tended to show less priming. A measure reflecting the extent of priming in each subject was obtained by subtracting the mean estimate for unprimed words from the mean estimate for primed words. Correlations between these duration sensitivity and duration priming measures (r = 0.038 for the amnesic group, r = 0.26 for the control group), however, were nonsignificant for both groups.

Duration estimates were also analysed separately for identified and unidentified words, because the overall priming effects could be secondary to the failure to identify some unprimed words. This artifact could occur, for example, if identified words were given uniformly high ratings but unidentified words were automatically given the lowest rating. Indeed, overall ratings were slightly higher for identified words and priming effects were slightly smaller when unidentified words were excluded, as shown in Table 5. These priming effects, however, were still significant [$F(1, 16)=8.8$, $P=0.01$] and did not differ across groups [nonsignificant Priming × Group interaction, $F(1, 16)<1$]. There was also some evidence for priming effects in both groups when duration estimates for unidentified words were analysed separately, but the number of words was insufficient for a valid analysis.

Table 5. Mean duration estimates in Experiment 2 (identified words only)

	Group			
	Amnesic		Control	
Condition	SOA-1	SOA-3	SOA-1	SOA-3
Primed	1.96	2.23	1.91	2.94
Unprimed	1.66	2.09	1.72	2.70
Difference	0.30	0.14	0.19	0.24

Recognition. The proportion of words correctly recognized was 0.58 for the amnesic group and 0.93 for the control group. Recognition scores were clearly lower in the amnesic group [$F(1, 16)=33.0$, $P=0.001$]. Since the priming test provided an additional exposure to critical words prior to the recognition test, recognition scores were analysed as a function of whether SOA-1 or SOA-3 was used in Phase 4. Although recognition in both groups was slightly better for words exposed longer, the differences were nonsignificant [$F(1, 16)<1$].

Recognition was also analysed as a function of the responses made in Phase 4 for conditions in which this analysis was feasible. For each amnesic patient, critical words presented at SOA-1 were classified as *unprimed* if a duration estimate of 1 was given and as *primed* if a larger estimate was given. The recognition scores for primed words (0.58) and for unprimed words (0.55) were not significantly different from each other [$F(1, 8)=2.1$]. Assuming that recognition scores were above chance (0.33) and below ceiling, this finding demonstrates that recognition was stochastically independent of priming as measured by an enhanced duration estimate.

Finally, correlations were run to look for relationships between patients' recognition and priming scores. In general, the patients with larger priming effects were not necessarily the patients with smaller memory deficits. The size of priming effects did not correlate with the recognition scores either for identification ($r=-0.027$) or for duration estimates ($r=-0.013$).

Discussion

The amnesic patients were unimpaired on measures of identification priming and duration-estimation priming. This preservation of memory functions contrasts sharply with the results from direct memory tests. In fact, the amnesic patients were impaired at recognizing the same words used in the priming test when tested shortly afterwards. Identification priming in Korsakoff patients has been demonstrated previously [1], whereas duration-estimation priming has not been studied in neurologically impaired populations.

Both types of priming were found in our group of amnesic patients and we found no evidence for differences between the different aetiologies studied. Also, two findings weigh against the possibility that the priming results were an artifact of differential SOA settings between groups: (a) there were no significant differences between results from subgroups matched for SOA settings (as well as in the full groups), and (b) there were no clear effects of a 120 msec difference in SOA settings in Experiment 1.

The patients we selected were able to learn the duration-judgement task in Phase 2 of the experiment, although the training required patience and subjects in both groups found the task difficult at first. With practice all subjects achieved a level of performance above guessing, but the experimenter ended Phase 2 before any subject reached a performance level higher than 75%. The fact that the amnesics showed significant priming of duration estimations attests to their ability to use the arbitrary scale to categorize durations. Performing the task can be conceived as a skill; amnesics may have learned this skill normally. Similarly, a case study using a time-estimation task showed that a 5 sec interval was estimated accurately by an amnesic patient and control subjects, whereas longer intervals were underestimated to a relatively greater extent by the patient than by the controls [19]. On the other hand, it is interesting to note that patients with cerebellar damage showed impairments in the perception of duration in a task in which two successive intervals were compared, suggesting that cerebellar circuitry is critical for certain timing functions [7]. At any rate, the amnesics succeeded in learning both the rules of the task and an effective strategy, although their strategy may have been different, and perhaps less effective, than that used by the controls.

Further inspection of the behavioural measures revealed that the amnesics were not performing the task in the same way as were the control subjects. In particular, the amnesics tended to restrict their responses to the lower portion of the duration scale. This tendency could reflect a difficulty in maintaining a memory for the four specific durations. During the test, the constantly displayed card reminded subjects which end of the scale referred to the faster flashes, but durations were demonstrated explicitly only in Phase 2. The control subjects may have been able to base their judgements on episodic memories associated with each of the four durations shown in Phase 2. The amnesic patients, in contrast, may have based their judgements on a comparison between their memory for the current exposure duration and the previous few durations. An intact immediate memory alone could conceivably provide this useful information about previous stimuli. But because only two durations were shown in Phase 4, the amnesics may have utilized a poorer basis for their judgements. Perhaps if four durations were to be used instead, the amnesics would have better anchors for the scale and so not refrain from using the full range, but this procedural change would need to be tested to verify that it did not disrupt the priming effects.

The use of only two durations may, however, be critical for obtaining the priming effects. By one account, duration-estimation priming arises when subjects erroneously attribute relative perceptual fluency to the duration of stimulus presentation [10, 11]. This scenario requires that subjects have a degree of uncertainty about the stimulus variable in question. In the duration-estimation paradigm, it may be critical that subjects are uncertain about their duration judgements. Using only two durations may contribute to this uncertainty. When a subject is uncertain about a judgement, he or she may be more likely to base the judgement on other information such as perceptual fluency.

The duration estimate has a number of advantages for studying priming. Most examples of repetition priming involve the repetition of multiple processes, from perception to response.

With word identification, for example, repetition priming could conceivably involve more effective perceptual processing, more effective access to lexical representations, and more effective motor processing underlying the identification response. This type of priming effect might arise because of increased efficiency in any of a number of processes. In the present case, the response of estimating the duration was not executed during the study phase. Therefore, the direct impact of repetition priming for duration estimations must have been associated with perceptual, lexical, or perhaps semantic processing rather than with response processing. Duration estimations are also advantageous because no reference need be made to the prior learning episode. Accordingly, performance may not be influenced significantly by conscious recollection of the studied words. Even if subjects did engage in explicit retrieval, an effect on duration estimates would not necessarily follow. Furthermore, the lack of significant correlations between patients' scores for recognition and duration-estimation priming suggests that priming scores were uncontaminated by residual recognition abilities in the amnesic patients.

Given that amnesic patients can show normal priming effects, what is it exactly that they can remember normally? Apparently a memory trace remains that is sufficient to support priming but insufficient to support recognition. Several hypotheses are consistent with this state of affairs (see [13]). Perhaps the remaining trace is suitable for simple memory feats such as priming but not rich enough for recall or recognition. According to JACOBY and KELLEY [10], normal recognition relies on two independent processes, *recollection* and *familiarity*, whereas amnesics have difficulty with recollection but not familiarity. Recollection may require relating target information to contextual features or depend critically on a consolidation process. Familiarity may not have these same requirements and may, in particular, not require as much effort or attention. Familiarity can be conceived as an outcome of an automatic attribution process in which an increase in relative perceptual fluency (or some other change) is attributed to prior experience. The evidence for normal duration-judgement priming in amnesics could be used to argue that the ability to make attributions based on fluency is intact. Hence, it is curious why amnesics fail to make normal attributions based on fluency with respect to recognition. The familiarity process clearly does not function normally. Further work is needed to determine why this is the case and whether the ability to make attributions of familiarity might be "retrainable" in certain amnesic patients.

The two indirect measures of memory used in the duration-judgement task indicated normal benefits of prior study in the amnesic patients. It should be stressed that recognition memory for the same words was severely impaired and that the intact priming was for words that had been highly familiar for all patients. Pre-existing representations of the material may or may not be necessary for priming to be normal in amnesia. However, the present results lay the groundwork for applying the duration-estimation task to study priming with novel material such as pronounceable nonwords.* This approach could thus provide additional important evidence useful for evaluating alternative theories of amnesia.

Acknowledgements—This research was supported by a Medical Research Council Project Grant (G8902677). We thank Les Law and Steve Rigby for technical assistance. We thank two anonymous referees for helpful comments.

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*We have obtained preliminary evidence for priming of identification and duration estimations in some amnesic patients when nonwords (consonant–vowel–consonant trigrams) were used (Paller, Mayes and Meudell, unpublished findings).

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