

THEORETICAL AND REVIEW ARTICLES

Consolidation theory and retrograde amnesia in humans

ALAN S. BROWN

Southern Methodist University, Dallas, Texas

Recent research on the cognitive dysfunctions experienced by human amnesic patients indicates that very long term (multidecade) changes may occur in memory. *Flat* retrograde amnesia (RA), consisting of a uniform memory deficit for information from all preamnesia time periods, indicates a simple, monolithic retrieval problem, whereas *graded* RA, with greater memory deficits for information from recent as opposed to remote time periods, suggests the presence of a gradual long-term encoding, or consolidation, process. An evaluation of 247 outcomes from 61 articles provides strong evidence of graded RA across different cerebral injuries, materials, and test procedures, as well as in measures of both absolute and relative (patient vs. control) performance. Future conceptualizations of human memory should address the possibility that memories increase in resistance to forgetting, or reduction in trace fragility, across many decades.

The concept of consolidation was introduced over a century ago by Müller and Pilzecker (1900; see also Burnham, 1903). While Müller and Pilzecker (1900) originally conceived of consolidation occurring over short periods of less than 10 min (cf. Lechner, Squire, & Byrne, 1999), their contemporary researchers appreciated that a concept of long-term consolidation could account for multiyear retrograde amnesia (RA) observed in individuals who had experienced head trauma (Burnham, 1903; Lechner et al., 1999; McDougall, 1901). This insight remains an important feature in the study of consolidation, and it will form the central organizing core of the present review.

There exist two different versions of the consolidation process (Wickelgren, 1974, 1977). In one, there is an absolute *increase in the strength* of the memory over time. In the other, consolidation consists of a *decrease in trace fragility*, where overall retrievability declines across time but the memory trace becomes more resistant to decay and retrograde amnesia (but *not* associative interference). Wickelgren (1974, 1977) suggested that the fragility decrease position is better supported by empirical findings, and that it accounts for the typical decreasing rate of decline (power function) observed in most long-term forgetting functions. Under both positions, it is assumed that "consolidation is an unconscious process that is assumed to be largely beyond voluntary control" (Wickelgren, 1977, p. 239).

A major problem with integrating the concept of consolidation into mainstream cognitive psychology is the difficulty of a direct empirical test in humans. Whereas animal research has repeatedly evaluated consolidation theory through postlearning experimental manipulations designed to either enhance (drugs) or block (electroshock) the consolidation process (McGaugh, 2000; Riccio & Richardson, 1984), most support for consolidation in humans is derived from the RA that usually accompanies brain trauma resulting from injury, vascular accident (infarct), infection, substance abuse (Korsakoff's), or degenerative neurological disease processes (e.g., Alzheimer's, Parkinson's, Huntington's). Although the phenomenon of RA has been reviewed repeatedly (Hodges, 1995; Kapur, 1993, 1999; Kopelman, 1989; Levin, Peters, & Hulkonen, 1983; Markowitz & Pritzl, 1985; Sporns & Tononi, 1994), it continues to pose a complex and intriguing mnemonic puzzle for researchers in a number of fields.

Examination of memory difficulties for information acquired prior to the trauma has traditionally taken a back seat to research on the difficulties in encoding new information experienced following the trauma, or anterograde amnesia (AA). The previous belief was that RA was vestigial to AA, in that the same encoding and/or retrieval disturbance that produced AA also caused RA as a side effect (Goldberg & Bilder, 1986). However, residual RA often persists even in cases in which temporary AA has cleared up, and some patients show RA accompanied by minimal or no AA (*focal* RA; Kapur, 1993). Thus, there is increasing suggestion that forms of RA may be the result of memory functions that are either partially or fully independent of AA, and examining RA may provide unique

Correspondence should be addressed to A. S. Brown, Department of Psychology, Southern Methodist University, Dallas, TX 75275-0442 (e-mail: abrown@smu.edu).

and independent insights into the operation of memory processes.

My purpose in the present article is not to review all facets of research involving RA. An excellent summary of the theoretical and empirical issues surrounding RA in humans has recently been provided by Kapur (1999). Furthermore, I will not attempt to make specific linkages between damage to particular brain structures and the extent, magnitude, and slope of the RA function. Most theorists concur that the extent of damage to the medial temporal lobes and to the hippocampus probably determines the severity of RA (see Nadel & Moscovitch, 1997; Squire & Alvarez, 1995). The more narrow objective of the present review is to examine the empirical evidence for the existence of a temporal gradient in RA among human amnesics, as well as its implication for the possible existence of long-term (multidecade) and continuous processes in memory formation.

There is an extensive experimental literature on consolidation in animals, involving the postacquisition administration of stimulant drugs to enhance consolidation or electroshock to interfere with consolidation (McGaugh, 2000). Although this research has provided numerous demonstrations of consolidation across a variety of species and tasks, there is considerable variability in the estimated length of the consolidation process (McGaugh, 2000; Polster, Nadel, & Schacter, 1991; Squire, 1992). The inability to clearly define the time course of consolidation in animals in research conducted during the 1970s became an impediment to refining the concept of consolidation (McGaugh & Gold, 1976; Polster et al., 1991), and Chorover (1976) elegantly demonstrated that "seemingly trivial" variations in the details of experimental procedures could have a sizeable influence on the magnitude of RA. However, in a recent review of animal studies conducted during the 1990s, Squire, Clark, and Knowlton (2001) found evidence of graded RA in most investigations (11 of 13 studies), and those included a variety of different species, tasks, and lesion techniques. Furthermore, the graded RA was found to extend across one or more months in a majority of these outcomes. Although I will not specifically address this animal literature in the present review, the findings complement the human research detailed here.

Over the past few decades, there has been a substantial increase in research evaluating amnesic patients' memory for events that have occurred up to 50 years prior to the onset of the amnesia state. Support for the existence of consolidation is derived from *graded* RA found in these data, with more recent memories impaired to a greater extent than more remote memories (Squire, 1989; Squire & Cohen, 1982; Squire, Cohen, & Nadel, 1984). Under consolidation theory, recently formed memory traces are more fragile than older memories, because they have had only a limited time to consolidate, making them less accessible or more difficult to retrieve after the occurrence of amnesia. In contrast, a monolithic or *flat* RA function, with memory diminished uniformly across all pretrauma time periods, does not support consolidation and suggests,

instead, a simple retrieval dysfunction (see De Renzi & Lucchelli, 1993; Kapur, 1993; Squire, 1987).

The controversy concerning the existence of graded RA in humans (Butters & Cermak, 1986; Cermak, 1984; Kapur, 1999) is highlighted in Table 1, which provides a listing of studies supporting graded RA as opposed to flat RA. These conclusions are expressed as either informal comments on patients' behavior, or formal conclusions derived from statistical analyses of data derived from standardized memory tests. Table 1 is intended to highlight areas of agreement and disagreement, not to provide a thorough and definitive summary. These studies suggest agreement concerning the presence of graded RA in Korsakoff's disease and ungraded RA in Huntington's disease. Regarding most of the other amnesic groups, the opinions are more equivocal.

Measurement of RA

Over 60 tests have been developed to measure memory performance over long time periods (a list appears in the Appendix). Most of these tests measure memory for people and events prominent in the news during a restricted time period. Although it is possible that such subjects could have learned about these people/events later in their lives, as in a historical inquiry (Squire & Slater, 1975), most researchers assume that the information has been encoded primarily during the temporal period in which the person or event first became newsworthy.

The concept of a graded memory performance is simple, but several issues surround its measurement. The primary problem is that it is difficult or impossible to know whether or *how well* any particular information experienced prior to the onset of amnesia has been encoded by an individual. Since there is no control over the degree of original learning prior to the amnesia, any deficiency in memory performance may be a result of the patient's poor (or nonexistent) encoding of the particular information, rather than a retrieval problem. A second, related problem is that of equating the difficulty of the information from each time period (Baddeley, Harris, Sunderland, Watts, & Wilson, 1987; Butters & Cermak, 1986; High, Levin, & Gary, 1990; Mayes et al., 1994; Squire & Cohen, 1982). If there are decade-to-decade differences in item difficulty, then performance differences across decades may be due to item nonequivalence rather than memory changes. Finally, little effort has been expended on generating norms for each test, updating the material with passing time, or assessing the comparability of different tests.

These difficulties of measurement present serious issues of interpretation for anyone attempting to evaluate individual outcomes derived from amnesic patients. However, examination of patients' performance *relative* to that of control individuals reduces the potential impact of these problems considerably. Variations in material difficulty across decades then become less relevant, since such differences have presumably affected both control and patient performance in similar ways. In the present paper, I will evaluate changes in amnesics' performance across time periods with both absolute and relative measures of

Table 1
Studies Claiming the Presence of Graded RA versus Flat RA

Korsakoff's	Graded RA: Albert, Butters, & Brandt (1981b); Albert, Butters, & Levin (1979); Butters (1984); Cohen & Squire (1981); Kopelman (1989); Marslen-Wilson & Teuber (1975); Meudell, Northern, Snowden, & Neary (1980); Montaldi & Parkin (1989); Seltzer & Benson (1974); Shimamura & Squire (1986); Squire & Cohen (1979, 1982); Squire, Haist, & Shimamura (1989); Verfaellie, Reiss, & Roth (1995). Flat RA: Sanders & Warrington (1971); Verfaellie et al. (1995).
Parkinson's	Graded RA: Sagar, Cohen, Sullivan, Corkin, & Growdon (1988). Flat RA: Beatty, Goodkin, Monson, Beatty, & Hartsgaard (1988); Freedman, Rivoira, Butters, Sax, & Feldman (1984); Huber, Shuttleworth, & Paulson (1986); Venneri et al. (1997).
Alzheimer's	Graded RA: Beatty, Salmon, Butters, Heindel, & Granholm (1988); Beatty & Solomon (1991); Kopelman (1989); Sagar et al. (1988). Flat RA: Dall'Ora, Della Sala, & Spinnler (1989); Daniel, Crovitz, & Weiner (1987); R. Wilson, Kasznik, & Fox (1981).
Huntington's	Graded RA: Flat RA: Albert, Butters, & Brandt (1981a); Beatty (1989); Beatty, Salmon, et al. (1988); Sagar et al. (1988); R. Wilson et al. (1981).
Multiple Sclerosis	Graded RA: Flat RA: R. Beatty, Goodkin, et al. (1988); Paul, Blanco, Hames, & Beatty (1997).
Closed head injury	Graded RA: Albert et al. (1981b); Levin et al. (1985); Tulving, Schacter, McLachlan, & Moscovitch (1988). Flat RA: Kapur, Ellison, Smith, McLellan, & Burrows (1992); Levin et al. (1985); Maravita, Spadoni, Mazzucchi, & Parma (1995); Papagno (1998).
Encephalitis	Graded RA: Carlesimo, Sabbadini, Loasses, & Caltagirone (1998); Kapur & Brooks (1999); Maravita et al. (1995); O'Connor, Butters, Miliotis, Eslinger, & Cermak (1992). Flat RA: Cermak & O'Connor (1983); Parkin, Montaldi, Leng, & Hunkin (1990); Tanaka, Miyazawa, Hashimoto, Nakano, & Obayashi (1999).
Mixed group	Graded RA: Daum, Flor, Brodbeck, & Birbaumer (1996); Kopelman, Wilson, & Baddeley (1989); Levin, Grossman, & Kelly (1977); MacKinnon & Squire (1989); Mayes, Daum, Markowitsch, & Sauter (1997); Rempel-Clower, Zola, Squire, & Amaral (1996); Squire et al. (1989). Flat RA: Mayes et al. (1994); Sanders & Warrington (1971, 1975); Verfaellie et al. (1995).
Tumor	Graded RA: Gainotti, Almonti, Di Betta, & Silveri (1998).
Lesion/Infarct/Anoxia	Graded RA: Barr, Goldberg, Wasserstein, & Novelty (1990); Beatty, Salmon, Bernstein, & Butters (1987); Beeckmans, Vancoillie, & Michiels (1998); Della Sala, Laiacona, Spinnler, & Trivelli (1993); D'Esposito, Alexander, Fischer, McGlinchey-Berroth, & O'Connor (1996); Gade & Mortensen (1990); Isaac et al. (1998); Milner (1959); Schnider, Regard, & Landis (1994); Squire et al. (1989); Winocur, Oxbury, Roberts, Agnetti, & Davis (1984). Flat RA: G. G. Brown, Kieran, & Patel (1989); Costello, Fletcher, Dolan, Frith, & Shallice (1998); Della Sala, Spinnler, & Venneri (1997); Ghika-Schmid et al. (1997); Kartounis, Rudge, & Stevens (1995); Katz, Alexander, & Mandell (1987); Levin, Grossman, & Kelly (1977); Levin et al. (1985); Mackenzie & Hodges (1997); Morris, Bowers, Chatterjee, & Heilman (1992); Schnider et al. (1994); Stuss, Guberman, Nelson, & Laroche (1988).
Uncertain etiology	Graded RA: Kapur, Young, Bateman, & Kennedy (1989); Kritchevsky & Squire (1993); Markowitsch, von Cramon, & Schuri (1993); Salmon, Lasker, Butters, & Beatty (1988).

memory. In some individual outcomes, these two measures actually lead to different conclusions. For example, Tanaka, Miyazawa, Hashimoto, Nakano, and Obayashi (1999) used six different memory tests with one amnesic

patient and concluded, primarily on the basis of absolute levels of performance, that there was no graded RA. Averaged across tests, memory performance was (from recent to remote decades) 50%, 68%, 69%, and 66%. Ex-

pressed as a percentage of control performance, however, a clear gradient emerges: 56%, 76%, 75%, and 104%.

Another issue considered in the aggregate analysis is the degree of retrieval support provided in the memory test. A recall test may be more sensitive to detecting memory deficits than a recognition test (Kapur, 1999). Furthermore, some research indicates that RA may represent the loss of contextual associations to encoded information (Parkin, Montaldi, Leng, & Hunkin, 1990; Tulving, Schacter, McLachlan, & Moscovitch, 1988; Verfaellie, Reiss, & Roth, 1995; Williams & Smith, 1954; Williams & Zangwill, 1952). Thus, graded RA may be present only with recall and may disappear when the degree of retrieval support is increased on a recognition test. As an illustration, Levin et al. (1985) found graded RA on autobiographical information in a recall test (Study 2), and ungraded RA on cultural information in a recognition test (Study 1). Similarly, Sagar, Cohen, Sullivan, Corkin, and Growdon (1988) found a temporal gradient for both Alzheimer's and Parkinson's patients on a recall test, but not on a recognition test. In the present paper, I will therefore analyze recall and recognition tests separately.

The presence of graded RA also appears to be related to the etiology of the amnesia, as is reflected in the disparity between Korsakoff's (graded RA) and Huntington's (flat RA) investigations summarized in Table 1. It has repeatedly been suggested that the temporal gradient found with Korsakoff's patients could be due to a progressive erosion in encoding efficiency accompanying the gradually escalating consumption of alcohol prior to the onset of Korsakoff's amnesia (Meudell, 1992; Montaldi & Parkin, 1989; Shimamura & Squire, 1986). As Mackenzie and Hodges (1997) point out, "it is widely recognized that patients with Korsakoff's syndrome are not an optimal group for examining the precise nature of retrograde amnesia. The onset of the memory impairment is difficult to date in these patients and they suffer from multiple neurological and cognitive impairments as a result of long-term, chronic alcohol abuse" (pp. 733–734). Many investigations of Korsakoff's patients use alcoholic controls to adjust for this potential problem, and expressing Korsakoff's performance relative to alcoholic controls helps factor out this problem. A similar argument can be made with neurologically degenerative diseases such as Huntington's and Parkinson's. As the disease slowly progresses, it may cause a gradual and systematic reduction in encoding efficiency which could result in graded RA. Therefore, the following data analyses will be done first as an aggregate, and then by subclasses of amnesia.

Criteria for Inclusion in Database

The database consists of 247 outcomes presented in 61 different published articles, evaluating a total of 694 patients. All studies included in this summary had a control group (or control individual) against which patients' performance could be compared. In the cases in which a range of control performance is presented (Costello, Fletcher, Dolan, Frith, & Shallice, 1998), the midpoint of the range is used as a reference. Another criterion for inclusion is

that the study had to have evaluated memory performance in at least two different time periods. These multiple time periods are defined two different ways. *Decade* studies evaluate memory for people and events from discrete, 10-year periods of time, whereas *life-stage* studies examine memory for personal experiences that have occurred in the early (childhood), middle (adolescence/early adulthood), and recent periods of life.

Excluded from this database are studies in which the amnesia is psychogenic (e.g., Binder, 1994; Gudjonsson & Taylor, 1985; Kessler et al., 1997; Schacter & Kihlstrom, 1989; Treatway, McCloskey, Gordon, & Cohen, 1992) or involves multiple personality disorder (Treatway et al., 1992) or fugue state (Keller & Shaywitz, 1986). The requirement of at least two decades necessitated the exclusion of studies with young patients (Carlesimo, Sabbadini, Loasses, & Caltagirone, 1998). Although there is a substantial body of research on RA effects associated with electro-convulsive therapy (or ECT), these studies were also excluded because the time periods evaluated in ECT research tend to be in the range of days to years, rather than decades.

The summary information for this meta-analysis is presented separately for decade (Table 2) and life-stage (Table 3) outcomes. The decade studies included 197 outcomes derived from 643 patients reported in 55 published articles. When time periods shorter than a decade were used (e.g., 5-year or 2-year intervals), these data were averaged by 10-year intervals (Gade & Mortensen, 1990; Hunkin et al., 1995; Seltzer & Benson, 1974). Where smaller time periods did not cumulate to at least two full decades, these outcomes were not included (Barr, Goldberg, Wasserstein, & Novelty, 1990; Cohen & Squire, 1981; Levin, Grossman, & Kelly, 1977; Levin et al., 1985). The life-stage studies included 50 outcomes derived from 173 patients and reported in 13 published articles (7 articles included both decade and life-stage tests). In nearly all cases, each life-stage period encompassed a time period greater than 10 years. In both the decade and life-stage studies, the data are often presented as frequency polygons or histograms. In these instances, performance levels were estimated from the figure. Across both decade and life-stage studies (Tables 2 and 3), the number of patients represented in each outcome ranges from 1 to 56 (median of 5 patients), with about a third (35%) derived from single cases.

The information on the outcomes presented in Tables 2 and 3 includes the type of amnesic group, as well as three subcategories of amnesia: Korsakoff's, neurodegenerative (Alzheimer's, Huntington's, Parkinson's, dementia, multiple sclerosis), and acute trauma (anoxia, closed head injury, encephalitis, infarct, infection, lesion, radiation, and transient global amnesia). The second and third categories are meant to differentiate between amnesias with insidious versus sudden onset. Although there is heterogeneity within each of the second and third groups of amnesics, any further differentiation would reduce the number of studies in the subgrouping to a problematic level.

The type of test was identified as either recall or recognition in decade studies (Table 2). Life-stage studies

Table 2
Summary Information for Decade Study Outcomes on RA

Study	Cat	Subcat	N	Age	Test	Mat	Decades Back										
							Absolute Percent						Relative Percent				
							1	2	3	4	5	6	1	2			
Albert, Butters, & Brandt (1981a)	Hunt	Neur	13	47	rcl	p	33	25	21	33	33		53	42	37	47	47
	Hunt	Neur	13	47	rcl	e	26	36	26	38	24		43	51	42	52	35
	Hunt	Neur	13	47	rcg	e	58	65	62	47	59	53	77	76	77	68	77
	Hunt	Neur	9	44	rcl	p	59	46	46	57	56		95	78	81	81	80
	Hunt	Neur	9	44	rcl	e	42	47	47	48	44		70	67	76	66	64
	Hunt	Neur	9	44	rcg	e	64	73	74	55	61	62	85	86	91	80	79
Albert, Butters, & Brandt (1981b)	Hunt	Neur	13	47	rcl	p	43	39	36	48	49		57	52	48	57	59
	Hunt	Neur	13	47	rcl	e	35	48	39	49	37		47	59	51	60	46
	Hunt	Neur	13	47	rcg	e	58	65	62	47	59		77	76	77	68	77
	Kors	Kors	8	53	rcl	p	18	35	42	62	63		24	47	57	74	76
	Kors	Kors	8	53	rcl	e	20	21	48	54	52		27	26	62	66	64
	Kors	Kors	8	53	rcg	e	47	57	62	52	59		63	67	77	75	77
Albert, Butters, & Levin (1979)	Kors	Kors	11	60	rcl	p	18	30	41	60	62		23	37	54	67	70
	Kors	Kors	11	60	rcl	e	16	24	43	51	53		21	29	52	61	63
	Kors	Kors	11	60	rcg	e	47	56	57	51	63		59	64	66	70	82
Babinsky, Spiske, Markowitsch, & Engel (1997)	Inft	Trau	1	36	rcl	p	60	34	60				94	71	94		
	Inft	Trau	1	36	rcg	e	100	40	31				103	47	49		
Barr, Goldberg, Wasserstein, & Novelty (1990)	Inft	Trau	6	38	rcl	p	36	35	47	39			39	44	49	43	
	Inft	Trau	6	38	rcl	p	100	83	85	73			81	89	105	109	
	Inft	Trau	6	38	rcl	e	15	36	37	42			20	41	45	51	
	Inft	Trau	6	38	rcl	e	52	73	71	77			69	84	87	93	
Beatty, Baily, & Fisher (1989)	Kors	Kors	1	39	rcl	e	32	40	53	67			40	45	60	92	
Beatty, Goodkin, Monson, Beatty, & Hartsgaard (1988)	Hunt	Neur	12	50	rcl	pe	47	46	41	57	44		82	77	72	84	73
	Alzh	Neur	12	70	rcl	pe	5	6	5	16	18		8	10	16	24	27
Beatty, Salmon, Bernstein, & Butters (1987)	Anox	Trau	1	54	rcl	p	36	57	43	84	85		55	89	72	111	112
	Anox	Trau	1	54	rcl	pe	17	37	51	78	90		25	52	78	108	118
Beatty, Salmon, Butters, Heindel, & Granholm (1988)	MS	Neur	28	49	rcl	pe	38	46	44	45	35		64	78	76	76	73
	MS	Neur	28	49	rcg	e	82	85	82	78	72		90	94	93	91	91
	MS	Neur	10	49	rcl	pe	15	14	17	27	19		25	24	29	46	40
	MS	Neur	10	49	rcg	e	57	68	64	63	58		63	76	72	73	73
Brandt & Benedict (1993)	Mix		7	71	rcg	e							33	38	56	65	48
Butters (1984)	Kors	Kors	2		rcl	p	19	36	42	62	62		24	47	56	74	74
	Kors	Kors	1		rcl	p	18	27	29	33	37		23	35	39	39	44
Butters & Albert (1982)	Hunt	Neur	13	50	rcl	p	46	42	42	53	48		61	58	58	63	58
	Hunt	Neur	13	50	rcl	e	33	45	44	47	37		45	56	58	57	46
	Kors	Kors	8		rcl	p	18	34	42	62	63		24	47	58	74	76
Butters & Cermak (1986)	Kors	Kors	1	65	rcl	e	1	0	26	42	50	67	1	0	26	42	50
Cermak & O'Connor (1983)	InfC	Trau	1	50	rcl	e	13	28	34	46	42		16	34	44	55	51
	InfC	Trau	1	50	rcl	p	12	32	37	46	48		16	43	49	55	59
	InfC	Trau	1	50	rcg	e	49	50	57	33	38		62	61	72	46	49
	Kors	Kors	2		rcl	e	20	22	47	53	51		25	27	60	64	62
	Kors	Kors	2		rcl	p	19	35	46	62	62		25	47	61	75	76
	Kors	Kors	2		rcg	e	50	61	62	55	66		63	74	78	76	85
Cohen & Squire (1981)	Lesn	Trau	1	40	rcg	e	86	63	83	74			95	78	106	100	
	Lesn	Trau	1	40	rcl	e	18	46	67	53			35	82	105	120	
	Lesn	Trau	1	40	rcl	p	45	43	67	79	80		71	73	129	149	170
	Kors	Kors	9	54	rcg	e	37	50	54	51			41	62	69	69	
	Kors	Kors	9	54	rcl	e	4	10	27	14			8	18	42	32	
	Kors	Kors	9	54	rcl	p	8	18	21	32	34		13	36	42	47	51

Table 2 (Continued)

Study	Cat	Subcat	N	Age	Test	Mat	Decades Back										
							Absolute Percent						Relative Percent				
							1	2	3	4	5	6	1	2			
Costello, Fletcher, Dolan, Frith, & Shallice (1998)							12	10	57				13	11	61		
Inft	Trau	1	45	rcg	p												
D'Esposito, Alexander, Fischer, McGlinchey-Berroth, & O'Connor (1996)							48	62	72	68			61	76	87	82	
Freedman, Rivoira, Butters, Sax, & Feldman (1984)																	
Park	Neur	8	65	rcl	p	57	49	66	61				84	71	84	75	
Park	Neur	14	64	rcl	p	64	70	71	74				94	101	90	91	
Gade & Mortensen (1990)																	
Inft	Trau	20	50	rcl	pe	40	50	48	58				64	76	71	74	
Inft	Trau	20	50	rcg	pe	73	80	76	77				85	88	88	83	
Alzh	Neur	19	55	rcl	pe	32	40	35	50				51	60	52	64	
Alzh	Neur	19	55	rcg	pe	63	72	70	77				73	79	81	83	
Infc	Trau	19	44	rcl	pe	34	48	48	63				53	72	71	81	
Infc	Trau	19	44	rcg	pe	68	80	76	90				79	87	87	97	
Huber, Shuttleworth, & Paulson (1986)																	
Park	Neur	11	63	rcl	p	76	76	72	79	61	74	100	96	109	104	92	112
Park	Neur	11	63	rcl	e	66	67	76	76	69	62	96	91	100	115	99	94
Park	Neur	11	63	rcg	e	72	76	66	60	70	65	103	95	100	98	93	116
Park	Neur	20	70	rcl	p	46	59	45	56	44	56	61	75	68	74	67	85
Park	Neur	20	70	rcl	e	40	50	60	45	46	41	58	68	79	68	66	62
Park	Neur	20	70	rcg	e	55	54	41	46	55	66	79	68	62	75	73	118
Hunkin et al. (1995)																	
CHI	Trau	1	19	rcl	e	56	50	75				71	71	104			
CHI	Trau	1	19	rcl	p	50	16	67				64	27	95			
Jackson & Bentall (1991)																	
Inft	Trau	1	49	rcl	p	100	77	45	20			102	77	57	41		
Kors	Kors	1	57	rcl	p	93	83	60	40			95	98	76	81		
Kapur & Brooks (1999)																	
Ence	Trau	1	46	rcg	p	34	63	70				39	75	96			
Ence	Trau	1	36	rcg	p	39	58					65	78				
Ence	Trau	1	36	rcg	e	50	80					53	80				
Kapur, Heath, Meudell, & Kennedy (1986)																	
TGA	Trau	1	70	rcl	e	25	25	60	40	55	20	39	45	158	87	162	333
TGA	Trau	1	70	rcg	e	65	63	85	75	60	20	78	79	127	114	98	87
TGA	Trau	1	70	rcl	p	6	11	8	8	5		9	19	21	16	17	
TGA	Trau	1	70	rcg	p	35	72	31	67	35		38	82	40	76	73	
Kors	Kors	5	59	rcl	e	13	21	26	21	18	3	20	38	68	46	53	50
Kors	Kors	5	59	rcg	e	50	60	63	61	50	36	60	75	94	92	82	157
Kors	Kors	5	59	rcl	p	13	18	14	26	13		20	31	37	53	45	
Kors	Kors	5	59	rcg	p	58	56	51	73	45		63	64	65	83	94	
Kapur et al. (1996)																	
CHI	Trau	1	46	rcl	e	13	10	26				22	36	46			
CHI	Trau	1	46	rcg	e	54	54	69				57	68	76			
Kapur, Young, Bateman, & Kennedy (1989)																	
TGA	Trau	1	74	rcl	e	17	10	0	21	11	20	31	25	0	63	51	38
TGA	Trau	1	74	rcg	e	0	10	30	20	34	60	0	13	36	26	46	88
TGA	Trau	1	74	rcg	p	30	43	70				43	58	95			
Kopelman (1989)																	
Alzh	Neur	16	68	rcl	e	8	10	16	22	27		12	18	28	42	48	
Alzh	Neur	16	68	rcg	e	36	38	42	47	46		45	48	51	69	66	
Kors	Kors	16	54	rcl	e	15	20	39	39	33		23	36	67	75	59	
Kors	Kors	16	54	rcg	e							57	70	79	79	82	
Kopelman, Stanhope, & Kingsley (1999)																	
Kors	Kors	13	54	rcl	e	39	37	52				49	58	76			
Kors	Kors	13	54	rcg	e	66	61	80				73	67	93			
Kors	Kors	13	54	rcl	p	48	50	46				67	70	77			
Mix	Trau	14	45	rcl	e	25	27	32				32	42	47			
Mix	Trau	14	45	rcg	e	60	56	57				67	62	66			
Mix	Trau	14	45	rcl	p	13	13	10				18	18	17			
Mix	Trau	15	46	rcg	e	47	37	55				59	58	81			
Mix	Trau	15	46	rcl	p	60	24	49				90	67	86			
Mix	Trau	15	46	rcg	p							83	34	82			
MacKinnon & Squire (1989)																	
Mix		5		rcl	pe							29	43	70	75	107	

Table 2 (Continued)

Study	Cat	Subcat	N	Age	Test	Mat	Decades Back										
							Absolute Percent						Relative Percent				
							1	2	3	4	5	6	1	2			
Markowitsch, Calabrese, et al. (1993)	CHI	Trau	1	45	reg	p	30	45	50	65			32	45	53	68	
	CHI	Trau	1	45	reg	p	5	15	20				20	60	80		
Markowitsch, von Cramon, & Schuri (1993)	Lesn	Trau	1	67	rcl	p	5	0	5	10	25		8	0	10	22	56
Markowitsch, Weber-Luxemburger, Ewald, Kessler, & Heiss (1997)	Anox	Trau	1	36	rcl	p	0	13	33				0	26	66		
Marslen-Wilson & Teuber (1975)	Lesn	Trau	1	46	rcl	p	8	19	68	71	50		11	28	71	122	128
	Kors	Kors	12	55	rcl	p	22	32	54	48	45		45	71	78	83	94
Mayes, Daum, Markowitsch, & Sauter (1997)	Infc	Trau	10	54	reg	e	63	63					67	75			
	Infc	Trau	10	54	rcl	p	4	5	16				13	23	42		
	Infc	Trau	10	54	rcl	p	23	28	48				36	54	67		
	Infc	Trau	10	54	reg	p	55	78					74	85			
	Infc	Trau	10	54	rcl	p	47	71					67	76			
Mayes, Meudell, Mann, & Pickering (1988)	Kors	Kors	1	55	rcl	p	11	0	6	10	0		17	0	16	20	0
	Kors	Kors	1	55	reg	p	67	70	47	70	26		73	80	60	80	54
	Kors	Kors	1	55	rcl	e	0	15	30	30	20		0	27	79	65	59
	Kors	Kors	1	55	reg	e	38	50	55	35	45		46	63	82	53	74
	Kors	Kors	1	64	rcl	p	11	0	6	25	20		17	0	17	51	69
	Kors	Kors	1	64	reg	p	50	50	41	80	59		54	57	53	91	123
	Kors	Kors	1	64	rcl	e	5	15	5	15	25		8	27	13	33	74
	Kors	Kors	1	64	reg	e	40	48	70	55	45		48	60	104	83	74
Meudell, Northern, Snowden, & Neary (1980)	Kors	Kors	5	59	rcl	p	12	12	14	26	13		19	20	37	53	43
	Kors	Kors	5	59	reg	p	58	56	51	72	46		64	64	65	82	94
Montaldi & Parkin (1989)	Kors	Kors	12	60	rcl	p	43	35	43	45	50		53	46	56	61	75
Parkin & Hunkin (1991)	Rad	Trau	1	34	rcl	e	14	6	38				14	8	43		
	Rad	Trau	1	34	rcl	p	17	33	50	33	33		19	44	59	51	67
Parkin, Montaldi, Leng, & Hunkin (1990)	Kors	Kors	20	63	rcl	p	30	27	42	43	50		38	36	54	58	79
Parkin, Rees, Hunkin, & Rose (1994)	Inft	Trau	1	48	reg	p							69	79	83		
	Kors	Kors	10		reg	p							0	27	39		
Reed & Squire (1998)	Inft	Trau	2	59	rcl	e	82	78					101	86			
	Inft	Trau	2	59	rcl	e	43	37	34				84	79	79		
	Inft	Trau	2	59	rcl	p	39	49	49				80	111	92		
	Inft	Trau	2	59	rcl	p	68	96	91				78	104	102		
	Inft	Trau	2	59	reg	e	96	98					101	101			
	Inft	Trau	2	59	reg	e	72	68	62				91	84	86		
	Inft	Trau	2	59	reg	p	76	94	92				87	106	97		
	Inft	Trau	2	59	reg	p	100	100	96				102	102	99		
	Infc	Trau	2	67	rcl	e	3	9	15	18			4	11	18	23	
	Infc	Trau	2	67	rcl	e	0	0	0	0	0*						
	Infc	Trau	2	67	rcl	p	0	0	0	0	0*						
	Infc	Trau	2	67	rcl	p	19	16	33	43			22	19	38	47	
	Infc	Trau	2	67	reg	e	31	39	44	75			32	40	45	79	
	Infc	Trau	2	67	reg	e	29	21	29	28			43	31	44	36	
	Infc	Trau	2	67	reg	p	52	47	51	50			65	49	62	60	
	Infc	Trau	2	67	reg	p	19	50	43	46			19	50	43	48	
Reinvang & Gjerstad (1998)	Inft	Trau	1	42	reg	pe	22	53	88				29	93	95		
Sagar, Cohen, Sullivan, Corkin, & Growdon (1988)	Alzh	Neur	8		rcl	e	36	36	25	30	57		52	47	37	52	70
	Alzh	Neur	27		reg	e	62	65	49	61	72		65	69	63	73	76
	Alzh	Neur	2		reg	e	48	54	52	56			63	75	69	77	
	Park	Neur	7		rcl	e							67	71	68	71	83
	Park	Neur	23		reg	e	89	83	76	70	83		94	88	97	95	87
	Park	Neur	20		reg	e	69	65	65	67			91	91	87	92	
Salmon, Lasker, Butters, & Beatty (1988)	Inft	Trau	1		rcl	pe	38	58	43	77	87		46	73	56	94	106

Table 2 (Continued)

Study	Cat	Subcat	N	Age	Test	Mat	Decades Back										
							Absolute Percent						Relative Percent				
							1	2	3	4	5	6	1	2			
Schmidtke & Vollmer (1997)	Inf	Trau	24	41	rcl	p							43	63	70		
	Inf	Trau	24	41	rcg	p							75	85	84		
Seltzer & Benson (1974)	Kors	Kors	11	56	rcg	e	50	51	64	82			57	61	76	95	
Shimamura & Squire (1986)	Kors	Kors	8	54	rcl	p	15	26	32	41			37	68	72	73	
	Kors	Kors	8	54	rcl	e	7	15	33	18			19	33	67	41	
	Kors	Kors	8	54	rcg	e	46	58	58	59			66	75	83	77	
Squire & Cohen (1982)	Lesn	Trau	1		rcl	p	44	42	66	79	80		70	72	130	149	170
	Kors	Kors	8	56	rcl	p	7	18	21	36	37		11	36	43	53	54
	Kors	Kors	8	56	rcg	p	53	63	64	77	79		57	71	74	82	85
Squire, Haist, & Shimamura (1989)	Kors	Kors	7	55	rcl	p	12	23	34	39	49		24	46	63	87	88
	Kors	Kors	7	55	rcg	p	61	79	77	80	88		66	86	86	96	102
	Kors	Kors	7	55	rcl	e	9	13	23	41			24	35	61	82	
	Kors	Kors	7	55	rcg	e	44	52	59	64			63	65	83	84	
	Mix		5	53	rcl	p	19	36	41	40	58		35	61	79	77	92
	Mix		5	53	rcl	e	81	90	87	90	95		83	93	90	99	100
	Mix		5	53	rcl	e	20	26	32	58			38	56	72	100	
	Mix		5	53	rcg	e	68	80	76	78			81	84	87	100	
Squire & Slater (1975)	Lesn	Trau	1		rcg	e	100	73	58				111	87	145		
	Lesn	Trau	1		rcl	e	30	3	10				43	33	133		
	Lesn	Trau	1		rcl	e	17	27	45				22	44	94		
	Lesn	Trau	1		rcg	e	80	77	83				94	94	111		
Squire et al. (1990)	Unkn		1		rcg	p	67	87	79	79	92		67	88	79	80	92
	Unkn		1		rcl	p	60	61	56	61	73		75	65	64	65	82
	Lesn	Trau	1		rcg	p	35	30	47	55	52		35	31	47	56	52
	Mix		1		rcl	p	40	16	19	32	10		47	17	22	34	11
Stuss, Guberman, Nelson, & Larochelle (1988)	Inft	Trau	1		rcg	e	40	38	40	78	47		66	56	65	95	66
Tanaka, Miyazawa, Hashimoto, Nakano, & Obayashi (1999)	Ence	Trau	1	43	rcl	e	18	38	31	35			28	58	47	70	
	Ence	Trau	1	43	rcg	e	64	81	86	84			66	85	93	104	
	Ence	Trau	1	43	rcl	p	20	87	69	49			23	98	77	123	
	Ence	Trau	1	43	rcg	p	80	100	100	100			80	100	100	142	
	Ence	Trau	1	43	rcl	e	40	20	40	50			57	33	40	83	
	Ence	Trau	1	43	rcg	e	80	80	90	80			80	80	90	100	
Verfaellie, Reiss, & Roth (1995)	Kors	Kors	7	62	rcl	e	25	39	43	60			36	52	59	64	
	Kors	Kors	7	62	rcg	e	63	67	72	80			70	76	82	83	
	Mix		7	41	rcl	p	52	68	76	79			72	86	92	94	
	Mix		7	41	rcg	p	83	86	89	94			90	94	94	96	
Wilson, Kaszniak, & Fox (1981)	Alzh	Neur	20	67	rcl	p	13	9	7	9	12		31	33	28	24	40
	Alzh	Neur	20	67	rcl	p	27	21	25	29	30		40	40	43	56	50
	Alzh	Neur	20	67	rcl	e	5	7	10	17	8		16	21	28	46	27
	Alzh	Neur	20	67	rcl	e	11	10	21	18	20		28	18	47	33	41

Note—Cat (Category): Alzh, Alzheimer's; Anox, anoxia; CHI, closed head injury; Ence, encephalitis; Hunt, Huntington's; Inft, infarct; Inf, infection; Kors, Korsakoff's; Lesn, lesion; Mix, mixture of amnesias; Park, Parkinson's; MS, multiple sclerosis; Rad, radiation; TGA, transient global amnesia; Unkn, unknown. Subcat (Subcategory): Kors, Korsakoff's; Neur, neurodegenerative; Trau, traumatic. Test: rcl, recall; rcg, recognition. Mat (material): p, people; e, events; pe, people and events. *These outcomes were excluded from the analyses (see text).

(Table 3) always used recall tests. In the investigations using both free and cued recall (e.g., Kopelman, Stanhope, & Kingsley, 1999), only free recall results are included, because all studies used a free recall test and only some followed up with a cued recall test. Thus, opting for cued recall would have considerably reduced the number of

outcomes presented. The type of information evaluated is also indicated. In decade studies (Table 2), this involved people (p), events (e), or a combination of people and events (pe). In life-stage studies (Table 3), experiences were either personal incidents (inc) or cultural semantic facts (sem). In both tables, patients' performance on ma-

Table 3
Summary Information for Life-Stage Study Outcomes on RA

Study	Cat	Subcat	N	Age	Test	Absolute Percent			Relative Percent		
						Recent	Middle	Early	Recent	Middle	Early
Costello, Fletcher, Dolan, Frith, & Shallice (1998)	Inft	Trau	1	45	inc	0	67	100	0	75	120
	Inft	Trau	1	45	sem	21	55	100	23	61	114
Daum, Flor, Brodbeck, & Birbaumer (1996)	Mix		10	53	inc	28	32	37	28	33	44
	Mix		10	53	sem	54	60	76	54	62	81
Kapur et al. (1994)	Alzh	Neur	1	49	sem	38	64	60	41	71	68
	Inft	Trau	1	49	sem	0	0	33	0	0	36*
Kopelman (1989)	Alzh	Neur	16	68	inc	39	57	59	42	65	70
	Alzh	Neur	16	68	sem	52	68	69	54	74	80
Kopelman, Stanhope, & Kingsley (1999)	Kors	Kors	16	54	inc	36	79	68	38	91	80
	Kors	Kors	16	54	sem	40	75	75	42	82	87
Kopelman, Stanhope, & Kingsley (1999)	Kors	Kors	13	54	inc	37	59	61	38	66	69
	Kors	Kors	13	54	sem	47	78	80	48	82	83
Kopelman, Wilson, & Baddeley (1989)	Mix		14	45	inc	49	56	48	51	63	54
	Mix		14	45	sem	63	75	73	65	79	77
Kopelman, Wilson, & Baddeley (1989)	Mix		15	46	inc	59	59	58	62	66	65
	Mix		15	46	sem	85	90	84	87	94	88
Kopelman, Wilson, & Baddeley (1989)	Anox	Trau	3		inc	33	48	51	40	55	59
	Anox	Trau	3		sem	62	80	77	65	88	88
Kopelman, Wilson, & Baddeley (1989)	Infn	Trau	2		inc	26	63	24	28	73	28
	Infn	Trau	2		sem	58	76	73	60	83	84
Kopelman, Wilson, & Baddeley (1989)	CHI	Trau	5		inc	49	41	46	53	47	53
	CHI	Trau	5		sem	56	64	77	58	70	88
Kopelman, Wilson, & Baddeley (1989)	Inft	Trau	3		inc	38	64	70	41	74	81
	Inft	Trau	3		sem	50	75	81	52	82	93
Kopelman, Wilson, & Baddeley (1989)	Dem	Neur	5		inc	51	71	71	55	82	82
	Dem	Neur	5		sem	44	80	73	45	88	84
Kopelman, Wilson, & Baddeley (1989)	Dem	Neur	3		inc	31	31	46	34	36	53
	Dem	Neur	3		sem	44	46	53	45	50	61
Kopelman, Wilson, & Baddeley (1989)	Infn	Trau	2		inc	28	36	41	30	41	47
	Infn	Trau	2		sem	19	40	44	19	43	50
Markowitsch, Calabrese, et al. (1993)	CHI	Trau	1	45	sem	64	57	29	64	62	33
	Mix		10	54	inc	39	42	48	39	45	51
Mayes (1995)	Mix		10	54	sem	55	67	74	55	71	76
	MS	Neur	44	46	inc	99	90	89	99	97	92
Paul, Blanco, Hames, & Beatty (1997)	MS	Neur	44	46	sem	92	97	92	99	93	93
	Reed & Squire (1998)	Inft	Trau	1	59	sem	80	86	93	85	94
Reed & Squire (1998)	Inft	Trau	1	59	sem	98	76	87	103	83	95
	Inft	Trau	1	59	inc	89	89	100	91	100	106
Reed & Squire (1998)	Inft	Trau	1	59	inc	78	100	89	80	113	94
	Inft	Trau	1	59	inc				101	101	98
Reed & Squire (1998)	Inft	Trau	1	59	inc				89	97	106
	Infn	Trau	1	74	sem	23	48	100	25	52	142
Reed & Squire (1998)	Infn	Trau	1	60	sem	5	14	24	5	16	34
	Infn	Trau	1	74	inc	0	67	100	0	77	132
Siegert & Warrington (1996)	CHI	Trau	1	2	inc	56	78	89	63	88	100
	CHI	Trau	1	2	sem	62	67	100	65	74	100
Tanaka, Miyazawa, Hashimoto, Nakano, & Obayashi (1999)	Ence	Trau	1	43	inc	0	11	33	0	11	50
	Wheatley & McGrath (1997)	Ence	Trau	1	43	sem	52	57	48	58	57
Wheatley & McGrath (1997)	Inft	Trau	1	37	inc	0	11	11	0	13	13
	Inft	Trau	1	37	sem	10	10	40	10	11	46

Note—Cat (Category): Alzh, Alzheimer's; Anox, anoxia; CHI, closed head injury; Dem, dementia; Ence, encephalitis; Infn, infection; Kors, Korsakoff's; Mix, mixture of amnesias; MS, multiple sclerosis. Subcat (Subcategory): Kors, Korsakoff's; Neur, neurodegenerative; Trau, traumatic. Test: inc, personal incidents; sem, semantic information. *This outcome was excluded from the analyses (see text).

terial from each different time period is expressed both as absolute percent correct (on a 100% basis) and as a relative percentage of control performance.

For the statistical analyses, each outcome is treated as a "subject," regardless of whether one or many patients contributed data. Three outcomes were excluded from the sta-

tistical analysis because of floor effects, where performance in half or more of the time periods tested was at 0% (Kapur et al., 1994; Reed & Squire, 1998), and these are marked by an asterisk (*) in the tables. Of the investigations in which patients were tested on more than one occasion, only the most recent test is used (D'Esposito,

Alexander, Fischer, McGlinchey-Berroth, & O'Connor, 1996; Tanaka et al., 1999). To illustrate, Cermak and O'Connor (1983) evaluated their patient (S.S.) in 1980 and again in 1981, but only the data from the 1981 test are used. In most instances, the memory evaluation was performed within a year or two after the onset of the amnesic state. The investigations with longer periods between amnesia onset and test usually restricted their memory evaluations to events that occurred prior to the amnesic state.

Since long-term consolidation is reflected in graded (as opposed to flat) RA, the primary statistical question is whether there is a significant linear trend for patients' performance across time periods. A quadratic trend analysis was also performed with three or more time periods. When there were three or fewer outcomes represented within a particular grouping, no statistical test was performed.

It is worth emphasizing that this collection of outcomes includes a wide variety of patient groups, test instruments, and content areas. Such methodological diversity should add considerable variance to the statistical analyses, so any statistically significant linear effect that might emerge under such circumstances should be considered robust. This aggregated data from a large variety of different tests, articles, and subject groups will hopefully allow trends to emerge that might not be apparent with any single empirical test.

Decade Analyses

Of the 195 analyzable outcomes in Table 2, eight involved measurement across two decades, 41 covered three decades, 49 involved four decades, 81 measured five decades, and 15 spanned six decades. One outcome covered seven decades, and this is incorporated into the six-decade analyses (with the 7th decade truncated). The same patient(s) were sometimes evaluated with more than one type of memory test, and each of these outcomes is separately listed in Table 2.

Analysis including all outcomes. Three different approaches were used to analyze the data from the decades studies. The first, presented in Table 4, considers each outcome as a unit of analysis. Each published study could contribute multiple outcomes to the database, depending on how many different memory tests were performed on each patient, or patient group, and how many different patients or patient groups were examined. To illustrate, Albert, Butters, and Brandt (1981b) evaluated two different groups of amnesic patients, one with Korsakoff's and one with Huntington's disease. Each group was evaluated three times, using a recall test for people, a recall test for events, and a recognition test for events. Thus, this study contributed six separate outcomes to this first analysis.

In Table 4, the data are first presented for all studies testing across two decades, then for all studies evaluating three decades, and so forth, on up to six decades. Each outcome is included in all decade analyses where it could possibly fit. Thus, every outcome in Table 2 is included in the two-decade analysis. Studies with a three-decade span are included in both the three-decade and two-decade

analyses; studies testing across four decades are included in the four-decade and three-decade and two-decade analyses, and so forth. Within each different decade-number analysis, the first data line summarizes all outcomes, followed by different subsets of outcomes for type of memory test (recall and recognition), information (people or events), and category of disorder (Korsakoff's, neurodegenerative, and acute). Tests that mixed people and events ("pe." from Table 2) are not included in either information subanalysis, and mixed groups of amnesics (or where the etiology of the amnesia is indeterminate) are not included in any patient subgroup analyses.

Although the analyses in Table 4 are subcategorized by five different decade ranges (two, three, four, five, and six), most comments will pertain to the decade ranges two through five because of the paucity of outcomes at six decades. In general, the outcomes presented in Table 4 reveal a very consistent pattern: a significant linear trend across decades, reflecting a systematic increase in patients' memory performance from more recent to more remote decades. A plot of the overall performance for each decade range for both absolute and relative performance, presented in Figure 1, illustrates these trends very clearly. It is especially striking that a significant overall linear trend is evident for both absolute and relative performance for all decade groups, with one exception—absolute performance in the six-decade analysis.

Graded RA is strongly evident for both recall and recognition tests. The only exception in decade analyses two through five is the lack of a linear trend in absolute recognition performance at five decades (which is significant in relative performance). Furthermore, graded RA is consistent across both types of information tested: people and events. With respect to amnesia type, both Korsakoff's and acute patients show clear graded RA. Neurodegenerative amnesias exhibit a much shallower gradient, with the linear trend significant in absolute performance for the two- and four-decade analyses, and in relative performance for the four- and five-decade analyses. Overall, 78 out of 80 comparisons presented in Table 4 yielded higher performance in the most remote as opposed to the most recent decade.

There are only occasional instances of a significant quadratic trend in these analyses. The most noteworthy example is in the overall absolute and relative performance for the five-decade analyses, which seems to reflect that the decade-to-decade increases in performance become less pronounced for more distant decades.

Analysis by patient or by patient group. In the second round of analysis on the decade studies, in instances in which multiple tests were performed on a patient or patient group, these are averaged into a single outcome. To illustrate, Albert et al. (1981b) contributed six outcomes to the prior analysis but only two outcomes to the present analysis—one for the Huntington's group and one for the Korsakoff's group (averaging across three different memory tests in both cases). When multiple tests on the same patient or patient group included differing numbers of

Table 4
Patients' Memory Performance for Decades Studies, With Each Outcome Included in All Appropriate Decades Analyses

Decades	N	Absolute Performance						Relative Performance									
		Decades Back						Decades Back									
		1	2	3	4	5	6	N	1	2	3	4	5	6	Linear F	Quad F	
Two	182	40	45					16.95***	190	51	58				34.74***		
Recall	112	30	34					8.90**	115	43	50				22.93***		
Recog	70	56	61					8.07**	75	64	71				11.72**		
People	79	39	44					8.21**	83	50	58				17.27***		
Events	89	42	45					3.58	92	53	58				9.41**		
Korsak	52	31	36					23.11***	54	38	49				48.65***		
Neurod	39	45	48					6.02*	40	63	64				<1		
Trauma	82	42	47					4.11*	85	53	61				11.60***		
Three	174	39	43	49				48.75***	<1	182	50	57	68		111.03***	3.57	
Recall	109	30	33	40				46.01***	2.65	112	42	49	62		76.65***	3.24	
Recog	65	56	60	63				8.26**	<1	70	64	70	78		36.06***	<1	
People	75	38	43	48				18.62**	<1	79	49	57	65		47.74***	<1	
Events	85	41	43	50				24.30***	5.45*	88	52	56	71		51.11***	15.11***	
Korsak	52	31	36	43				42.25***	<1	54	38	49	62		102.56***	1.75	
Neurod	38	45	48	46				<1	39	63	64	65			2.00	<1	
Trauma	75	41	44	52				21.22***	2.56	78	51	59	74		51.43***	2.42	
Four	140	38	44	47	52			78.73***	<1	144	49	56	65	72	137.94***	<1	
Recall	90	29	34	40	46			62.95***	<1	92	40	49	59	68	96.20***	<1	
Recog	50	55	61	61	64			19.44***	1.39	52	63	69	75	80	57.61***	<1	
People	60	38	43	45	53			25.07***	<1	60	47	56	62	72	44.02***	<1	
Events	68	38	43	49	51			46.50***	4.49*	71	49	56	68	72	97.84***	1.80	
Korsak	49	30	36	42	49			60.56***	<1	50	38	48	61	68	160.64***	1.90	
Neurod	38	45	48	46	49			3.96*	<1	39	63	64	65	69	11.04**	2.25	
Trauma	44	38	46	51	56			26.94***	1.13	44	46	57	68	79	47.38***	<1	
Five	94	34	39	43	49	48		53.10***	12.05***	97	45	51	62	69	72	88.63***	7.79**
Recall	64	25	30	36	44	43		65.38***	6.61*	66	37	44	57	65	69	73.29***	4.79*
Recog	30	54	59	58	60	58		1.99	5.54*	31	62	68	74	77	24.43***	2.97	
People	44	32	37	40	51	47		33.16***	4.16*	44	42	50	57	69	74	46.42***	<1
Events	44	38	43	48	48	48		18.21***	8.47**	46	49	54	68	68	37.62***	11.09**	
Korsak	38	28	34	41	49	46		42.39***	16.95***	38	35	45	59	67	70	151.57***	6.26*
Neurod	32	43	46	43	46	45		1.97	<1	33	60	61	63	66	64	7.80**	<1
Trauma	19	27	35	43	53	50		23.83***	5.49*	19	37	48	67	79	87	31.04***	1.89
Six	15	43	47	52	50	50	47	<1	2.45	16	58	61	78	76	77	103	6.35*
Recall	8	36	39	46	47	44	43	<1	2.59	8	51	55	76	75	80	105	2.78
Recog	7	52	57	60	62	56	51	<1	<1	8	64	66	80	77	75	101	6.68*
People	2	61	68	59	68	53	65			2	81	86	89	89	80	99	
Events	13	40	44	51	47	49	42	<1	2.58	14	54	57	77	74	77	104	6.09*
Korsak	3	21	27	38	41	39	35			3	27	38	63	60	62	91	
Neurod	8	60	65	62	58	58	60	2.20	<1	8	82	82	86	85	81	93	1.94
Trauma	4	27	27	44	39	40	30	<1	1.11	4	37	41	80	73	89	137	1.88

*p < .05. **p < .01. ***p < .001.

decades, the summary included only the decades encompassed by all tests. For example, Markowitsch, Calabrese, et al. (1993) tested their patient across four decades on one test and three on another, so the summary data for that patient encompasses three decades. Most averaged outcomes combine the results from different test formats (recall and recognition) and/or content areas (events and people), so these separate subanalyses do not appear in the summary presented in Table 5. Although the six-decade outcomes are presented, the number is sufficiently small to limit its inclusion in the overall interpretation.

This second analysis of the decade studies reveals a pattern similar to that found in the first: a significant overall linear trend for each decade grouping for both absolute and relative performance. The mean overall performance for each decade range is summarized in Figure 2. As in the prior analysis, the graded RA is consistently significant for Korsakoff's amnesias. Furthermore, acute am-

nesics showed consistent linear trends for all instances except the absolute two-decade analysis (where the mean difference was in the graded direction). The neurodegenerative group showed the weakest trend. For absolute performance, a linear trend was significant only for the two-decade grouping, and for relative performance, linearity was significant in both the four- and five-decade groups. Of 20 possible decade pair comparisons (e.g., one vs. two, one vs. three, two vs. three, etc.) in the two- through five-decade overall analyses, absolute performance increased backward in time on 19 occasions for Korsakoff's, 15.5 times for neurodegenerative (splitting ties), and 19 times for acute. This was significant ($p < .05$) by a sign test for all three groups. Likewise, a similar count for the relative performance revealed increases 20 times for Korsakoff's, 16 for neurodegenerative, and 20 times for acute, and again these were all significantly higher than chance by a sign test ($p < .05$). Similar to the initial analysis, there are

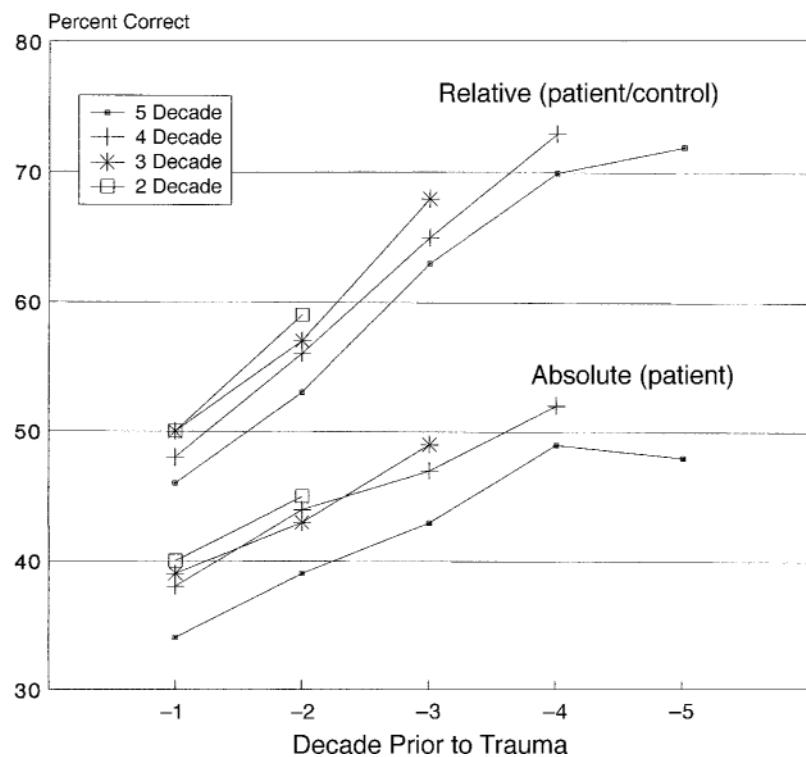


Figure 1. Patients' memory performance expressed in both *absolute* and *relative* (as a percentage of control performance) terms for decades studies, with each outcome counted in all appropriate decades analyses (overall decade summaries only).

occasional significant quadratic trends, mainly reflecting that the incremental memory improvement in amnesics' performance declines in size across decades.

Single-inclusion analysis. The third round of decade analysis considered each outcome under only one decade

subgroup. The outcomes evaluating two decades appeared only in the two-decade analyses; the outcomes spanning three decades appeared only in the three-decade analyses, and not in the two-decade analyses as well. This analysis reveals an outcome similar to the previous two (see Table 6).

Table 5
Patients' Memory Performance in Decades Studies, With One Outcome Per Patient or Patient Group

Decades	N	Absolute Performance						Relative Performance									
		Decades Back						Decades Back									
		1	2	3	4	5	6	N	1	2	3	4	5	6	Linear F	Quad F	
Two	81	40	43					86	50	57					19.38***		
Korsak	24	31	36					25	38	48					32.78***		
Neurod	20	49	51					22	65	66					<1		
Trauma	33	39	42					33	49	56					5.79*		
Three	77	39	42	49				83	50	56	66				53.86***	3.57	
Korsak	24	31	36	45				25	38	48	61				85.42***	<1	
Neurod	19	49	51	49				21	65	66	66				<1	<1	
Trauma	30	37	40	52				31	50	56	70				22.15***	2.97	
Four	63	40	44	49	54			68	50	56	64	72			58.98***	<1	
Korsak	23	30	36	44	50			23	39	48	61	69			95.00***	1.08	
Neurod	19	49	51	49	52			21	65	66	71				10.00**	5.56*	
Trauma	17	40	46	52	59			18	46	55	65	76			14.20**	<1	
Five	41	34	38	43	51	50		48	44	50	59	68	71		56.66***	2.43	
Korsak	16	25	31	41	48	46		17	34	44	58	66	71		167.18***	4.21	
Neurod	14	46	48	45	48	51		16	60	61	62	68	66		7.05*	<1	
Trauma	9	28	35	45	60	57		10	32	42	56	73	79		20.94**	<1	
Six	3	40	42	49	54	55	63	<1	2.45	7	44	49	65	67	103	9.91*	1.95

*p < .05. **p < .01. ***p < .001.

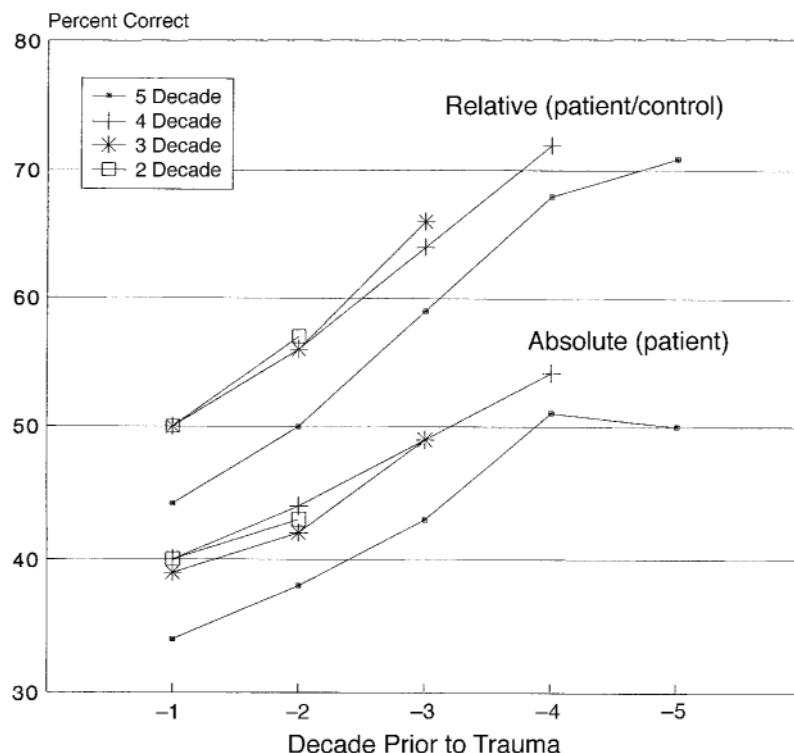


Figure 2. Patients' memory performance expressed in both *absolute* and *relative* (as a percentage of control performance) terms for decades studies, with each outcome counted in only one decade analysis (overall decade summaries only).

For absolute performance, there were significant overall linear trends in all but the six-decade analysis; for relative performance, there were significant overall linear trends in all but the two-decade grouping. Excluding the six-decade group, there were significant linear effects for Korsakoff's patients in five of six occasions where tests could be made. In the instances that were non-testable (absolute, three decade) and nonsignificant (absolute, four decade), there were still increases in mean performance backward across decades. The neurodegenerative group also showed

sakoff's patients in five of six occasions where tests could be made. In the instances that were non-testable (absolute, three decade) and nonsignificant (absolute, four decade), there were still increases in mean performance backward across decades. The neurodegenerative group also showed

Table 6
Patients' Memory Performance for Decades Tests, With Each Outcome Included in Only One Decade Analysis

Decades	N	Absolute Performance						N	Relative Performance						Linear F	Quad F	
		Decades Back							Decades Back								
		1	2	3	4	5	6	Linear F	Quad F	1	2	3	4	5	6	Linear F	Quad F
Two	8	59	72					7.92*		8	75	82				2.61	
Trauma	7	62	75					6.74*		7	75	83				2.44	
Three	33	47	43	55				4.07*	13.37***	37	57	61	80			27.29***	6.37*
Korsak	3	51	49	59						4	47	56	71			15.50*	<1
Trauma	30	46	42	55				3.41	11.95**	31	59	61	81			21.37***	7.00*
Four	47	46	52	56	59			16.96***	1.91	47	56	65	71	79		38.37***	<1
Korsak	12	37	41	48	51			4.22	<1	12	46	57	69	73		22.34***	1.77
Neurod	6	56	58	60	64			12.71*	<1	6	76	80	77	80		1.07	<1
Trauma	25	46	54	57	58			6.40*	2.37	25	53	64	68	78		17.91***	<1
Five	78	32	38	41	49	47		55.76***	9.44**	81	43	50	59	68	71	82.30***	4.24*
Korsak	34	28	34	41	49	46		41.71***	21.32***	35	36	46	59	67	71	134.55***	4.48*
Neurod	24	38	39	37	42	41		6.64*	<1	25	53	54	55	60	59	9.12**	<1
Trauma	15	27	37	43	56	53		21.39***	3.95	15	36	50	63	80	86	22.34***	1.67
Six	15	43	47	52	50	50	47	<1	2.45	16	58	61	78	76	77	103	6.35*
Korsak	3	21	27	38	41	39	35			3	27	38	63	60	62	91	
Neurod	8	60	65	62	58	58	60	2.20	<1	8	82	82	86	85	81	93	1.94
Trauma	4	27	27	44	39	40	30	<1	1.11	4	37	41	80	73	89	137	1.88

*p < .05. **p < .01. ***p < .001.

Table 7
Patients' Memory Performance for Life-Stage Tests

Test	Absolute Performance					Relative Performance						
	N	Recent	Middle	Early	Linear F	Quad F	N	Recent	Middle	Early	Linear F	Quad F
Two Stages	47	46	61		34.79***		49	50	68		44.91***	
Incidents	22	39	57		16.73***		24	46	67		21.27***	
Semantic	25	51	64		18.96***		25	53	69		25.69***	
Korsak	4	40	73		56.27***		4	42	80		52.57**	
Neurod	9	55	67		6.15*		9	57	73		8.02*	
Trauma	32	44	59		18.11***		32	49	67		24.23***	
Three Stages	47	46	61	66	30.25***	8.70*	49	50	68	76	35.48***	7.40**
Incidents	22	39	57	61	12.98**	8.52*	24	46	67	73	15.01***	8.62**
Semantic	25	51	64	71	16.98***	1.67	25	53	69	80	20.34**	<1
Korsak	4	40	73	71	164.74***	23.00*	4	42	80	80	143.03**	21.18*
Neurod	9	55	67	68	9.19*	3.20	9	57	73	76	12.90**	3.47
Trauma	32	44	59	66	15.68***	2.87	32	49	67	78	18.48***	2.11

p* < .05. *p* < .01. ****p* < .001.

significant linear trends in three of four tests (excluding the six-decade grouping), and the acute group yielded significant linear effects in six of eight tests. In short, there was again a marked consistency in the linear trends for memory performance. In fact, of 34 comparisons presented in Table 6, thirty-three showed higher mean performance in the most distant than in the most recent decade. A count of the number of increases in paired decade comparisons across the two- through five-decade analyses revealed the consistent significant differences (sign test) for both absolute (Korsakoff's, 17/19; neurodegenerative, 13/16; acute, 18/20) and relative (Korsakoff's, 19/19; neurodegenerative, 12.5/16; acute, 20/20) performance.

Life-Stage Patients

The analyses in Table 7 include the patients evaluated on memory of events and information experienced during three stages of their life: early (childhood), middle (adolescence/early adulthood), and recent (later adulthood). To parallel the decade patients' analyses, both absolute and relative performance for the 50 outcomes were analyzed first by two periods back (recent and middle) and then by three periods back (recent, middle, and early). All studies evaluated three time periods and thus appeared in both the two- and three-period analyses. As in the decade analyses, an overall analysis is presented first, followed by separate subanalyses by material (incidents and semantic) and patient category (Korsakoff's, neurodegenerative, and

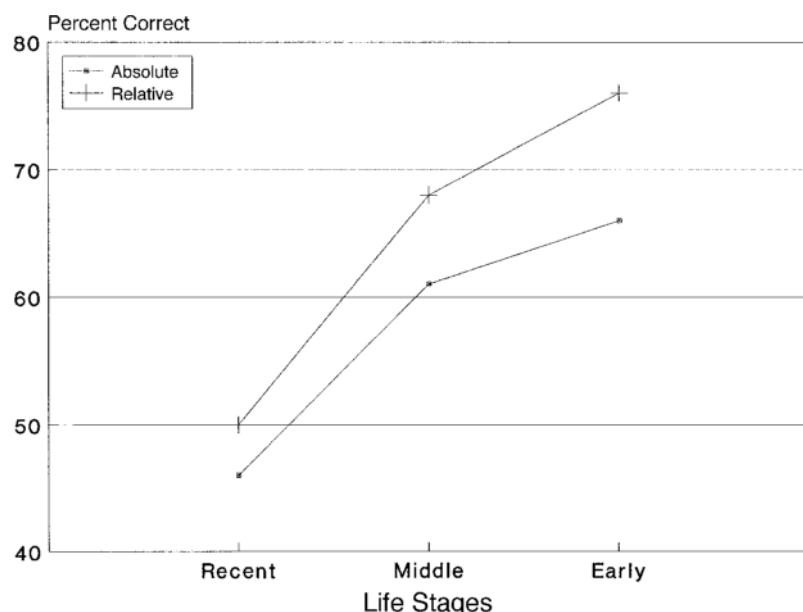


Figure 3. Patients' memory performance expressed in both *absolute* and *relative* (as a percentage of control performance) terms, with each patient or patient group counted only once (overall life-stage summaries only).

trauma). A summary of the overall performance is provided in Figure 3.

These analyses again confirm the presence of graded RA, with significant linear trends for absolute and relative performance in all 24 analyses. This increase in memory performance is steeper from the recent to middle periods, and it moderates somewhat from the middle to the early periods. This moderation is reflected in the significant overall quadratic trend for the three-stage analysis. The presence of graded RA is clear for all three patient groups, and for tests of both semantic and incident information. In short, the life-stage analyses provide additional support for the existence of graded RA over long temporal intervals generally comprising four to seven decades.

Discussion

The analyses presented in this paper provide clear support for the existence of long-term (multidecade) consolidation processes in humans (Wickelgren, 1977). More specifically, amnesic patients show a consistent backward increase in memory performance for information acquired prior to the onset of their amnestic state. This evidence of graded RA is apparent in both absolute performance scores and in performance measured relative to controls. This trend is evident for more precisely defined (decades) as well as less precisely defined (life-stage) time periods. Furthermore, it is reliable across amnesias caused by Korsakoff's disease, neurodegenerative diseases, and acute head injury. Although graded RA is considerably flatter for the neurodegenerative amnesias, it is still apparent in most comparisons.

Graded RA is consistently found with memory for both people and events in the decades studies (Table 4). An examination of the data analyses presented in Table 4 shows a consistent linear trend for both people and events across decade groupings two through five. The only exception (out of 16 tests) is absolute performance on events at two decades. A series of supplementary analyses of variance (ANOVAs) was conducted on decade groupings two through five to determine whether there were any differences in linearity for people versus events. ANOVAs were performed on both absolute and relative memory performance; the two variables were test type (people, events) and decade. These consistently revealed no main effects of material (people vs. events; all $F_s < 1$) and no interaction of linearity \times material (all $F_s < 3.78$) in any of the analyses. Similarly, four ANOVAs on the life-stage outcomes compared semantic and incident material in both two-stage and three-stage groupings, with both absolute and relative performance measures (see Table 7). This series of ANOVAs again revealed no main effect of material (semantic vs. incidents; all $F_s < 2.53$) or interaction of linearity \times material (all $F_s < 1$) in any analysis. Thus, within the limits of measurement error, it appears that magnitude and slope of graded RA are consistent across different material, whether this involves people versus events (decade studies) or personal incidents versus semantic knowledge (life-stage studies).

In a similar manner, a comparison was made of the form of graded RA derived from recall versus recognition tests in the decade studies (Table 4). Some have suggested that the presence or absence of graded RA is dependent on the particular tests used (Kapur, 1999). More specifically, whereas graded RA is found with recall, flat RA results from recognition tests (Levin et al., 1985; Sagar et al., 1988). The analyses of the decade studies, presented in Table 4, appear to settle this issue by showing consistent graded RA for both recall and recognition. More specifically, across the two- through five-decade groupings, recall showed a significant linear trend in all eight tests (absolute and relative measures in each of four decade groupings) and recognition was significant in seven of eight tests (the only exception was five decades, absolute performance). A more subtle question is whether the slope of the graded RA differs between the two types of tests. Again, eight separate ANOVAs compared recall and recognition for both absolute and relative performance, separately for each of the two- through five-decade groupings. Recognition was consistently and significantly higher than recall (all $p_s > .001$), and there was no interaction of linearity \times test in the two- and three-decade analyses (all $F_s < 3.35$). However, there was a significant interaction of linearity \times test ($p_s < .01$) at both the four-decade [absolute $F(1,138) = 6.86$; relative $F(1,142) = 7.51$] and five-decade [absolute $F(1,92) = 16.41$; relative $F(1,95) = 8.08$] analyses. The interactions reflect the fact that the graded RA is steeper for recall than for recognition, although both recognition and recall evidence show consistent linearity.

To summarize, the present analyses provide strong empirical support for the concept of long-term memory consolidation. More specifically, information stored in memory appears to become progressively more resistant to forgetting across many decades. Although the evidence is compiled from a large number of different studies using diverse sets of patient types with a wide variety of different assessment instruments, the strength of this meta-analysis is derived from the consistency of the outcomes. Particularly important is that both the relative and absolute measures of performance indicate graded RA, and that there are only minimal differences between the summary analyses from each perspective. Interestingly, reevaluating the animal studies on RA from the 1990s (Squire et al., 2001) by relative rather than absolute RA provides even stronger support for graded RA: Squire et al. (2001) found that 11 of 13 outcomes show an *absolute* gradient, but all 13 outcomes yield a *relative* gradient.

The absolute RA gradient might superficially suggest that consolidation involves an increase in the strength of the trace (see Wickelgren, 1974, 1977). However, this may be a function of the manner in which the test materials are developed. For decade studies, an attempt was made to equate performance levels across decades in the control group. To achieve this, information evaluated from three decades back probably comprises easier-to-retrieve (stronger) items than items evaluating one decade back. Put another

way, if a test were developed today, items from the 1990s would probably contain a higher proportion of peripheral (vs. central) facts than would an item set from the 1970s to equate the performance level for the two decades at around 80%. If the same set of items (from the 1990s) were presented again 20 years from now, it would probably yield a much lower level of performance. Life-stage outcomes also show the same absolute RA gradient *without* item sets equated on strength; the high degree of selectivity of specific items in the life-stage studies makes it difficult to use these data to support a strength increase interpretation of consolidation. Although it is not possible to eliminate the strength-increase position on the basis of these analyses, it seems more reasonable to assume that consolidation involves a progressive reduction in "fragility" over time (see Wickelgren, 1977).

Coverage of long-term consolidation commonly appeared in textbooks on memory and cognition written in the 1970s and early 1980s (Baddeley, 1976; Crowder, 1976; Ellis, Bennett, Daniel, & Rickert, 1979; Flaherty, Hamilton, Gandelman, & Spear, 1977; Horton & Turnage, 1976; Houston, 1981; Hulse, Deese, & Egeth, 1975; Kintsch, 1970; Stern, 1985; Wickelgren, 1977; Zechmeister & Nyberg, 1982). Some of these books even devoted most or all of a chapter to the topic (Baddeley, 1976; Wickelgren, 1977; Zechmeister & Nyberg, 1982). However, discussion of consolidation—sometimes called *trace theory*—has been essentially absent in textbooks published within the past 15 years. One reason why consolidation theory has not become fully rooted in the literature on human learning and memory is that it operates apart from conscious awareness. Also problematic is the vague

way in which the theory was originally framed (Stern, 1985). For instance, such basic questions as "how long does complete consolidation take?" and "what mechanism mediates the unconscious process?" were left unaddressed. Finally, the strong influence of new technologies (T-scope; computer interfaces) and stage models of memory (e.g., that of Shiffrin & Atkinson, 1969) introduced in the 1970s directed research attention toward short-term, and away from long-term, memory storage. There has, however, been a recent reemergence of the concept of consolidation in speculations concerning human amnesia (Alvarez & Squire, 1994; Cohen & Squire, 1981; Dudai, 1996; Kapur & Brooks, 1999; Knowlton & Fanselow, 1998; Lechner et al., 1999; McGaugh, 2000; Moscovitch & Nadel, 1998; Murre, 1996; Nadel & Moscovitch, 1997; Polster et al., 1991; Squire, 1986, 1989, 1992; Squire & Alvarez, 1995; Westmacott, Leach, Freedman, & Moscovitch, 2001). In fact, Schacter's (1996) recent popular book on memory devotes considerable discussion to consolidation, partially as a result of new developments in the field of neuropsychology as well as a renewed interest in studying amnesia.

As stated earlier, several criticisms have been voiced concerning research on RA. Aside from the lack of consistency across instruments or refinement of individual memory tests, differences in memory performance across time periods might be attributed to differences in the inherent difficulty of test items sampled from each period. Furthermore, there is a lack of control over whether, or how well, the information has initially been encoded by the patients. The present analyses address such difficulties by evaluating patients' performance relative to a comparable

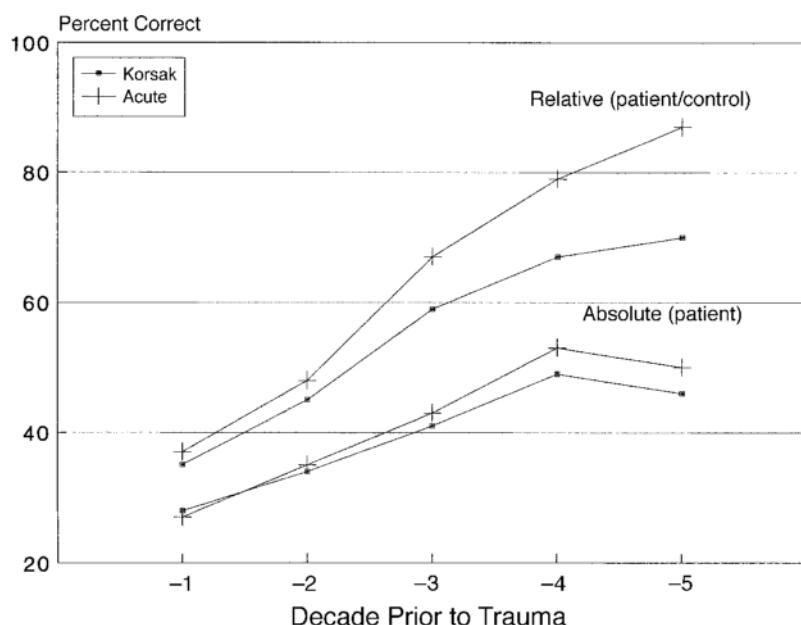


Figure 4. Memory performance for Korsakoff's and acute patient subgroups expressed in both absolute and relative (as a percentage of control performance) terms for all decades studies testing five decades.

set of memory-intact control individuals. Any differences across decades in item difficulty should be reduced or eliminated by expressing performance in such form. And surprisingly, graded RA functions based on absolute and relative performance are remarkably similar and differ only in magnitude.

It has also been suggested that a degenerative neurological disease might progressively erode the quality of memory encoding, resulting in reduced recollection for events more proximal to the onset of the amnesic state. This argument has typically been applied to Korsakoff's disease (Butters & Albert, 1982; Butters & Granholm, 1987; Squire & Cohen, 1982), where there is a combination of progressive neurological and cognitive deficits resulting from a protracted habit of heavy drinking (MacKenzie & Hodges, 1997). As noted earlier, many of the investigations of Korsakoff's patients use alcoholic controls to accommodate this possibility. However, the same argument cannot be applied to instances in which the onset of the injury is sudden, such as closed head injury, cerebral lesion, or infarct. The comparable temporal gradient found in the acute patient group argues against an artifactual account of a temporal gradient in RA with Korsakoff's disease, unless one takes the unparsimonious stance that different processes produce similar gradients in different amnesic groups. The comparability in the temporal gradients for patients with amnesia of acute onset and patients with amnesia of more gradual onset (Korsakoff's syndrome) illustrated in Figure 4 (derived from the five-decade summary in Table 4) makes it difficult to argue that the Korsakoff's gradient is due to a progressive erosion in encoding efficiency prior to the development of the amnesic state.

Several other interpretative frameworks, aside from consolidation theory, have been proposed to account for graded RA. The earliest explanation, suggested by Ribot (1882) and later known as "Ribot's Law" (see Markowitz & Pritzl, 1985), was that the susceptibility of a particular memory to disruption is inversely proportional to its age. That is, the older a memory is, the more resistant it is to loss due to head injury. Although some researchers have used this "law" as a theoretical framework within which to present their findings (Albert, Butters, & Levin, 1979; Daniel, Crovitz, & Weiner, 1987; Marslen-Wilson & Teuber, 1975), it is more descriptive than explanatory. Ribot proposed no mechanism whereby this resistance to forgetting/disruption occurred. Others have similarly proposed that the older the memory, the more resistant it is to amnesia (cf. Squire, Haist, & Shimamura, 1989) or the less susceptible it is to interference (cf. Zechmeister & Nyberg, 1982). All of these perspectives are in concert with consolidation theory in that memories become progressively more resistant to forgetting over time, whether that resistance comes from deeper encodings, greater fortification against retrieval disruption, or better insulation from interference. The advantage of consolidation theory over these other perspectives, other than historical precedent, is that it suggests a dynamic mechanism and has been de-

veloped in greater detail by recent proponents (Alvarez & Squire, 1994; Knowlton & Fanselow, 1998; Lechner et al., 1999; McGaugh, 2000; Moscovitch & Nadel, 1998; Nadel & Moscovitch, 1997).

Another explanation for graded RA has been proposed by Cermak (1987), who suggests that episodic memories gradually change into semantic memories with sufficient rehearsal (Gade & Mortensen, 1990; Meudell, 1992; Stuss & Guzman, 1988; Verfaellie et al., 1995). Thus, oft recalled older events (the Challenger explosion) become part of semantic memory through repeated contemplation. A gradient in RA thus reflects a reduction in the number of (relatively weaker) episodic memories as they change into (relatively stronger) semantic memories. The greater the proportion of semantic memories, the lower the likelihood that disease processes or trauma involving the brain can disrupt access to the memories.

There are several difficulties with this episodic–semantic shift as a viable alternative to consolidation theory. If semantic memories resist disruption, there should be a difference between the outcome for the semantic information and incidents (episodic) information evaluated in the life-stage patients (in Table 7). More specifically, there should be flat RA for both semantic and incidents information, with semantic performance significantly higher than incidents. In actuality, there are comparable levels of graded RA for both types of information, as has been demonstrated in the previous analyses. Another problem with the episodic–semantic shift interpretation is that it is difficult to believe that the amount of reflection on prior experiences does not diminish with time. Realistically, there should be a drastic reduction in the slope of the graded RA function after 10 years, but this is not the case. Figures 1 and 2 suggest no diminution in the backward increase in performance across five decades. It is hard to imagine that events three to four decades ago receive an amount of rehearsal comparable to that for events experienced one decade ago. In contrast, consolidation theory assumes a progressive and continual strengthening of the information, a position more in line with the observed changes across time periods.

This review has focused on a comparison of flat RA and graded RA, but other forms of retrograde memory dysfunction exist as well. Temporal dating confusion often occurs for pretrauma memories (Goody, 1964), as well as backward displacement of memories, wherein events are thought to have occurred much longer ago than they actually have. There may also be periods with no memories, sandwiched in between periods of mnemonic lucidity ("patchy" RA) (Blomert & Sisler, 1974; Corkin, Hurt, Twitchell, Franklin, & Yin, 1987; Hall, 1963; Kapur, 1993; Markowitz & Pritzl, 1985; Ogden & Corkin, 1991; Rose & Symonds, 1960; Squire, 1987). During recovery after traumatic head injury, there is usually a gradual reduction in the extent of RA (Benson & Geschwind, 1967; Blomert & Sisler, 1974; Russell & Nathan, 1946; Williams & Zangwill, 1952), with more distal memories recovering first. Some have suggested that shrinking RA

is evidence contrary to consolidation theory (Benson & Geschwind, 1967). However, if access to information (speed, probability) is directly related to the amount of consolidation undergone by that information, then it is reasonable to expect that more remote memories should be easier to retrieve during a period of temporarily diminished cerebral (retrieval) function.

The nearly universal view concerning the neural basis of long-term consolidation is that it consists of two distinct mechanisms: Information is initially processed in the medial temporal lobe (MTL) and related structures (including the hippocampus), and the MTL then orchestrates the distribution of the information to multiple cortical locations. The older and more popular perspective is that the MTL has a *time-limited* participation in the consolidation process (Alvarez & Squire, 1994; Dudai, 1996; Halgren, 1984; Knowlton & Fanselow, 1998; McGaugh, 2000; Milner, 1972; Murre, 1996; Schmidke & Vollmer, 1997; Squire, 1987; Squire & Alvarez, 1995; Squire, Knowlton, & Musen, 1993; Teyler & DiScenna, 1986; Treves & Rolls, 1994; Wickelgren, 1979), although researchers differ on whether the MTL acts simply as a cortical arousal agent (Wickelgren, 1979), provides an index (pointers) to guide the formation and maintenance of interconnections among information storage sites in the cortex (Teyler & DiScenna, 1986), or contains a complete copy of the memory which is gradually duplicated in various cortical locations (Alvarez & Squire, 1994; Halgren, 1984; McClelland, McNaughton, & O'Reilly, 1995; Treves & Rolls, 1994).

An alternative to this interpretation of consolidation has recently been introduced by Moscovitch and his colleagues (Moscovitch & Nadel, 1998; Nadel & Moscovitch, 1997; Westmacott et al., 2001); it differs from the previous position in two important respects. First, consolidation of information consists of the generation of multiple copies of the same memory, rather than the "strengthening" of a single version of the memory. Second, the MTL complex remains essential to the maintenance and retrieval of the information, no matter what the age of the memory. Although the present outcome cannot clearly differentiate between these various positions, a reasonable conclusion is that both MTL structures and cortical sites are essential for continued consolidation because amnesia resulting from damage to the MTL structures or cortical degeneration both yield evidence of graded RA. More specifically, although the MTL may continue to orchestrate the multiple cortical sites involved in a particular memory, the continued coordinated interaction among those particular locations, apart from the MTL involvement, is also essential for the continuation of the consolidation process.

Although the empirical reality of long-term consolidation is becoming more apparent in both human and animal research, the details of this process are far from clear (Dudai, 1996; Squire et al., 2001). For instance, exactly how does the hippocampus form linkages to disparate cortical areas where memories are stored? And does consol-

idation occur continually, or only during special brain states such as REM sleep (Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994; Winson, 1985)? Finally, what is the adaptive value of a lifelong process whereby memories show a progressive reduction in trace fragility (Knowlton & Fanselow, 1998; McGaugh, 2000; Moscovitch & Nadel, 1998; Nadel & Moscovitch, 1997; Wickelgren, 1974)? Dudai (1996) has proposed that consolidation is adaptive because the slow growth in memory representations maintains a continually plastic memory store that can readily accommodate new and emerging conceptualizations of the world. McGaugh (2000) similarly suggests that consolidation has adaptive value for the organism by "enabling endogenous processes activated by an experience to modulate memory strength" (p. 248).

Another possible value in the continual strengthening of memory is to counteract the natural demise in memory accessibility with age (Knowlton & Fanselow, 1998). MacKay (1987) has suggested that one reason why older adults experience more retrieval difficulties, such as the tip-of-the-tongue experience (see A. S. Brown, 1991, 2000), is that the linkages between the semantic and lexical representational systems weaken with age and disuse. Perhaps consolidation helps to counteract the natural decline through autonomous neurological updating and the refreshing of these network linkages.

A small body of literature has examined long-term (multi-decade) maintenance of information in nonamnesic older adults. For instance, Bahrick and his colleagues (Bahrick, 1983, 1984; Bahrick & Hall, 1991; Bahrick, Hall, Goggin, Bahrick, & Berger, 1994) examined the very long-term retention of information learned during high school (Spanish vocabulary words; mathematical concepts; spatial maps) and concluded that if information is not learned well, it will be completely forgotten within 3–5 years. However, if it is adequately encoded, it will enter "permastore" and persist essentially undiminished across 50 years (Bahrick, 2000).

There is some debate about this concept of *permastore*. Hintzman (1990) suggests that the flat retention function actually reflects declining academic standards rather than unchanging strength of the stored memories. To support his claim, he shows that when the flat (permastore) portion of Bahrick's (1984) retention function for language learned in high school and college is adjusted for grade inflation and decrease in mandatory language requirement, this yields a progressively declining retention function. Other demonstrations of permastore, however, do not involve academic material (high school classmates, Bahrick, Bahrick, & Wittlinger, 1975; street names learned during childhood, Schmidt, Peeck, Paas, & van Breukelen, 2000) and thus avoid Hintzman's criticism.

If one assumes that the concept of permastore is valid, there is a discrepancy between the flat function revealed in these analyses and the performance increase revealed in the present analysis of RA data. A possible explanation is that most information evaluated in permastore research is isolated with respect to type of material and time of ac-

quisition. For instance, Spanish language (Bahrick, 1984) or classmates' names (Bahrick et al., 1975) learned in high school and street names learned in childhood (Schmidt et al., 2000) are unlikely to be rehearsed or reencountered beyond the initial acquisition experience. In contrast, the type of information tested in most RA studies is more likely to be continually reencountered (historical events), updated (famous people), and rehearsed (vocabulary). Thus it is possible that long-term consolidation is more likely with material that has a higher probability of repeated personal reflection or cultural reexposure.

In summary, the important conclusion derived from the analyses presented in this article is that the formation of permanent memories may take much longer than the span of working, or conscious, memory function. The fact that graded RA is comparable in both absolute and relative performance measures suggests that the outcome is not an artifact of the measurement scale or of differences in item difficulty across decades. This graded RA is comparable across different materials (people and events; personal incidents and semantic information) and different memory test procedures (recall and recognition). Furthermore, graded RA is consistent across different amnesic groups, although the slope is distinctly shallower for neurodegenerative disorders. The RA gradient appears to persist across four or five decades without substantial diminution. The occasional significant quadratic trend generally reflects a decrease in the magnitude of the decade-to-decade memory increases at more remote decades.

Thus, there appears to be considerable evidence for a type of dynamic and continual memory storage process that is decades long and that operates apart from conscious awareness (see Abel et al., 1995). As Deutsch (1962) aptly proposed, "compared with that from animals, the evidence from retrograde amnesia in man suggests an entirely different time scale, that of years or a lifetime for the period of consolidation" (p. 267). Any future speculations concerning the dynamics of human memory storage should certainly include a serious consideration of such long-term consolidation processes.

REFERENCES

- ABEL, T., ALBERINI, C., GHIRARDI, M., HUANG, Y., NGUYEN, P., & KANDEL, E. R. (1995). Steps toward a molecular definition of memory consolidation. In D. L. Schacter (Ed.), *Memory distortion* (pp. 298-325). Cambridge, MA: Harvard University Press.
- ALBERT, M. A., BUTTERS, N., & BRANDT, J. (1981a). Development of remote memory loss in patients with Huntington's disease. *Journal of Clinical Neuropsychology*, **3**, 1-12.
- ALBERT, M. A., BUTTERS, N., & BRANDT, J. (1981b). Patterns of remote memory in amnesic and demented patients. *Archives of Neurology*, **38**, 495-500.
- ALBERT, M. S., BUTTERS, N., & LEVIN, J. A. (1979). Temporal gradients in the retrograde amnesia of patients with alcoholic Korsakoff's disease. *Archives of Neurology*, **36**, 211-216.
- ALVAREZ, P., & SQUIRE, L. R. (1994). Memory consolidation and the medial temporal lobe: A simple network model. *Proceedings of the National Academy of Sciences*, **91**, 7041-7045.
- BABINSKY, R., SPISKE, K., MARKOWITSCH, H. J., & ENGEL, H. (1997). Clinical case report: Memory functions after anterior communicating artery aneurysm rupture. *International Journal of Neuroscience*, **91**, 265-275.
- BADDELEY, A. (1976). *The psychology of memory*. New York: Basic Books.
- BADDELEY, A., HARRIS, J., SUNDERLAND, A., WATTS, K. P., & WILSON, B. A. (1987). Closed head injury and memory. In H. S. Levin, J. Grafman, & H. M. Eisenberg (Eds.), *Neurobehavioral recovery from head injury* (pp. 295-317). New York: Oxford University Press.
- BAHICK, H. P. (1983). The cognitive map of a city: 50 years of learning and memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 17, pp. 125-163). New York: Academic Press.
- BAHICK, H. P. (1984). Semantic memory content in permastore: 50 years of memory for Spanish learned in school. *Journal of Experimental Psychology: General*, **113**, 1-29.
- BAHICK, H. P. (2000). Long-term maintenance of knowledge. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 347-362). New York: Oxford University Press.
- BAHICK, H. P., BAHRICK, P. O., & WITTLINGER, R. P. (1975). Fifty years of memory for names and faces: A cross-sectional approach. *Journal of Experimental Psychology: General*, **104**, 54-75.
- BAHICK, H. P., & HALL, L. K. (1991). Lifetime maintenance of high school mathematics content. *Journal of Experimental Psychology: General*, **120**, 20-33.
- BAHICK, H. P., HALL, L. K., GOGGIN, J. P., BAHRICK, L. E., & BERGER, S. A. (1994). Fifty years of language maintenance and language dominance in bilingual Hispanic immigrants. *Journal of Experimental Psychology: General*, **123**, 264-283.
- BARR, W. B., GOLDBERG, E., WASSERSTEIN, J., & NOVELLY, R. A. (1990). Retrograde amnesia following unilateral temporal lobectomy. *Neuropsychologia*, **28**, 243-255.
- BEATTY, W. W. (1988). The Fargo Map Test: A standardized method for assessing remote memory for visuospatial information. *Journal of Clinical Psychology*, **44**, 61-67.
- BEATTY, W. W. (1989). Remote memory for visuospatial information in patients with Huntington's disease. *Psychobiology*, **17**, 431-434.
- BEATTY, W. W., BAILLY, R. C., & FISHER, L. (1989). Korsakoff-like amnesia syndrome in a patient with anorexia and vomiting. *International Journal of Clinical Neuropsychology*, **11**, 55-65.
- BEATTY, W. W., GOODKIN, D. E., MONSON, N., BEATTY, P. A., & HARTSGAARD, D. (1988). Anterograde and retrograde amnesia in patients with chronic progressive multiple sclerosis. *Archives of Neurology*, **45**, 611-619.
- BEATTY, W. W., SALMON, D. P., BERNSTEIN, N., & BUTTERS, N. (1987). Remote memory in a patient with amnesia due to hypoxia. *Psychological Medicine*, **17**, 657-665.
- BEATTY, W. W., SALMON, D. P., BUTTERS, N., HEINDEL, W. C., & GRANHOLM, E. L. (1988). Retrograde amnesia in patients with Alzheimer's disease or Huntington's disease. *Neurobiology of Aging*, **9**, 181-186.
- BEATTY, W. W., & SOLOMON, D. P. (1991). Remote memory for visuospatial information in patients with Alzheimer's disease. *Journal of Geriatric Psychiatry & Neurology*, **4**, 14-17.
- BEECKMANS, K., VANCOILLIE, P., & MICHEELS, K. (1998). Neuropsychological deficits in patients with an anterior communicating artery syndrome: A multiple case study. *Acta Neurologica Belgica*, **98**, 266-278.
- BENSON, D. F., & GESCHWIND, N. (1967). Shrinking retrograde amnesia. *Journal of Neurology, Neurosurgery, & Psychiatry*, **30**, 539-544.
- BINDER, L. M. (1994). Psychogenic mechanisms of prolonged autobiographical retrograde amnesia. *Clinical Neuropsychologist*, **8**, 439-450.
- BLOMERT, D. M., & SISLER, G. C. (1974). The measurement of retrograde post-traumatic amnesia. *Canadian Psychiatric Association Journal*, **19**, 185-192.
- BRANDT, J., & BENEDICT, R. H. B. (1993). Assessment of retrograde amnesia: Findings with a new public events procedure. *Neuropsychology*, **7**, 217-227.
- BROWN, A. S. (1991). A review of the tip of the tongue phenomenon. *Psychological Bulletin*, **109**, 204-223.
- BROWN, A. S. (2000, June). *Aging and the tip-of-the-tongue experience*. Paper presented at the American Psychological Society Convention.
- BROWN, G. G., KIERAN, S., & PATEL, S. (1989). Memory functioning following a left medial thalamic hematoma. *Journal of Clinical & Experimental Neuropsychology*, **11**, 206-218.

- BURNHAM, W. H. (1903). Retroactive amnesia: Illustrative cases and a tentative explanation. *American Journal of Psychology*, **14**, 118-132.
- BUTTERS, N. (1984). Alcoholic Korsakoff's syndrome: An update. *Seminars in Neurology*, **4**, 226-244.
- BUTTERS, N., & ALBERT, M. (1982). Remote memory, retrograde amnesia, and the neuropsychology of memory. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 257-274). Hillsdale, NJ: Erlbaum.
- BUTTERS, N., & CERMAK, L. S. (1986). A case study of the forgetting of autobiographical knowledge: Implications for the study of retrograde amnesia. In D. C. Rubin (Ed.), *Autobiographical memory* (pp. 253-272). Cambridge: Cambridge University Press.
- BUTTERS, N., & GRANHOLM, E. (1987). The continuity hypothesis: Some conclusions and their implications for the etiology and neuro-pathology of alcoholic Korsakoff's syndrome. In O. A. Parsons, N. Butters, & P. E. Nathan (Eds.), *Neuropsychology of alcoholism: Implications for diagnosis and treatment* (pp. 176-206). New York: Guilford.
- CARLESIMO, G. A., SABBADINI, M., LOASSES, A., & CALTAGIRONE, C. (1998). Analysis of the memory impairment in a post-encephalitic patient with focal retrograde amnesia. *Cortex*, **34**, 449-460.
- CERMAK, L. S. (1984). The episodic-semantic distinction in amnesia. In L. R. Squire & N. Butters (Eds.), *Neuropsychology of memory* (pp. 55-62). New York: Guilford.
- CERMAK, L. S. (1987). Models of memory loss in Korsakoff and alcoholic patients. In O. A. Parsons, N. Butters, & P. E. Nathan (Eds.), *Neuropsychology of alcoholism: Implications for diagnosis and treatment* (pp. 207-226). New York: Guilford.
- CERMAK, L. S., & O'CONNOR, M. (1983). The anterograde and retrograde retrieval ability of a patient with amnesia due to encephalitis. *Neuropsychologia*, **21**, 213-224.
- CHOROVER, S. L. (1976). An experimental critique of "consolidation studies" and an alternative model systems approach to the psychobiology of memory. In M. R. Rosenzweig & E. L. Bennett (Eds.), *Neural mechanisms of learning and memory* (pp. 561-582). Cambridge, MA: MIT Press.
- COHEN, N. J., & SQUIRE, L. R. (1981). Retrograde amnesia and remote memory impairment. *Neuropsychologia*, **19**, 337-356.
- CORKIN, S. H., HURT, R. W., TWITCHELL, T. E., FRANKLIN, L. C., & YIN, R. K. (1987). Consequences of nonpenetrating and penetrating head injury: Retrograde amnesia, posttraumatic amnesia, and lasting effects on cognition. In H. S. Levin, J. Grafman, & H. M. Eisenberg (Eds.), *Neurobehavioral recovery from head injury* (pp. 318-329). New York: Oxford University Press.
- COSTELLO, A., FLETCHER, P. C., DOLAN, R. J., FRITH, C. D., & SHALLICE, T. (1998). The origins of forgetting in a case of isolated retrograde amnesia following a haemorrhage: Evidence from functional imaging. *Neurocase*, **4**, 437-446.
- CROWDER, R. G. (1976). *Principles of learning and memory*. Hillsdale, NJ: Erlbaum.
- DALL'ORA, P., DELLA SALA, S., & SPINNLER, H. (1989). Autobiographical memory: Its impairment in amnesic syndromes. *Cortex*, **25**, 197-217.
- DANIEL, W. F., CROVITZ, H. F., & WEINER, R. D. (1987). Neuropsychological aspects of disorientation. *Cortex*, **23**, 169-187.
- DAUM, I., FLOR, H., BRODBECK, S., & BIRBAUMER, N. (1996). Autobiographical memory for emotional events in amnesia. *Behavioural Neurology*, **9**, 57-67.
- DELLA SALA, S., LAIACONA, M., SPINNLER, H., & TRIVELLI, C. (1993). Autobiographical recollection and frontal damage. *Neuropsychologia*, **31**, 823-839.
- DELLA SALA, S., SPINNLER, H., & VENNERI, A. (1997). Persistent global amnesia following right thalamic stroke: An 11-year longitudinal study. *Neuropsychology*, **11**, 90-103.
- DE RENZI, E., LIOTTI, M., & NICHELLI, P. (1987). Semantic amnesia with preservation of autobiographical memory: A case report. *Cortex*, **23**, 575-597.
- DE RENZI, E., & LUCCELLI, F. (1993). Dense retrograde amnesia, intact learning capability and abnormal forgetting rate: A consolidation deficit? *Cortex*, **29**, 449-466.
- D'ESPOSITO, M., ALEXANDER, M. P., FISCHER, R., MCGLINCHEY-BERROTH, R., & O'CONNOR, M. (1996). Recovery of memory and executive function following anterior communicating artery aneurysm rupture. *Journal of the International Neuropsychological Society*, **2**, 565-570.
- DEUTSCH, J. A. (1962). Higher nervous function: The physiological bases of memory. *Annual Review of Physiology*, **24**, 259-286.
- DUDAI, Y. (1996). Consolidation: Fragility on the road to the engram. *Neuron*, **17**, 367-370.
- ELLIS, H. C., BENNETT, T. L., DANIEL, T. C., & RICKERT, E. J. (1979). *Psychology of learning and memory*. Monterey, CA: Brooks/Cole.
- FLAHERTY, C. F., HAMILTON, L. W., GANDELMAN, R. J., & SPEAR, N. E. (1977). *Learning and memory*. Chicago: Rand McNally.
- FREEDMAN, M., RIVOIRA, P., BUTTERS, N., SAX, D. S., & FELDMAN, R. G. (1984). Retrograde amnesia in Parkinson's disease. *Canadian Journal of Neurological Science*, **11**, 297-301.
- GABRIELI, J. D. E., COHEN, N. J., & CORKIN, S. (1988). The impaired learning of semantic knowledge following medial temporal-lobe resection. *Brain & Cognition*, **7**, 157-177.
- GADE, A., & MORTENSEN, E. L. (1990). Temporal gradient in the remote memory impairment of amnesic patients with lesions in the basal forebrain. *Neuropsychologia*, **28**, 985-1001.
- GAINOTTI, G., ALMONTI, S., DI BETTA, A. M., & SILVERI, M. C. (1998). Retrograde amnesia in a patient with retrosplenial tumour. *Neurocase*, **4**, 519-526.
- GHIGA-SCHMID, F., GHIGA, J., VUILLEUMIER, P., ASSAL, G., VUADENS, P., SCHERER, K., MAEDER, P., USKE, A., & BOGOUSSLAVSKY, J. (1997). Bihippocampal damage with emotional dysfunction: Impaired auditory recognition of fear. *European Neurology*, **38**, 276-283.
- GOLDBERG, E., & BARNETT, J. (1985). Effects of ECT on various types of remote memory. *Journal of Clinical & Experimental Neuropsychology*, **7**, 145.
- GOLDBERG, E., & BILDER, R. M. (1986). Neuropsychological perspectives: Retrograde amnesia and executive deficits. In L. W. Poon (Ed.), *Handbook for clinical memory assessment of older adults* (pp. 55-68). Washington, DC: American Psychological Association.
- GOODY, W. (1964). Some comments on the significance of retrograde amnesia, with an analogy. *Brain*, **87**, 75-86.
- GRAFF-RADFORD, N. R., ESLINGER, P. J., DAMASIO, A. R., & YAMADA, T. (1984). Nonhemorrhagic infarction of the thalamus: Behavioral, anatomic, and physiological correlates. *Neurology*, **34**, 14-23.
- GROSSI, D., TROJANO, I., GRASSO, A., & ORSINI, A. (1988). Selective semantic amnesia after closed head injury: A case report. *Cortex*, **24**, 457-464.
- GUDJONSSON, G. H., & TAYLOR, P. J. (1985). Cognitive deficit in a case of retrograde amnesia. *British Journal of Psychiatry*, **147**, 715-718.
- HALGREEN, E. (1984). Human hippocampal and amygdala recording and stimulation: Evidence for a neural model of recent memory. In L. R. Squire & N. Butters (Eds.), *The neuropsychology of memory* (pp. 165-182). New York: Guilford.
- HALL, P. (1963). Korsakoff's syndrome following herpes-zoster encephalitis. *Lancet*, **1**, 752.
- HIGH, W. M., LEVIN, H. S., & GARY, H. E. (1990). Recovery of orientation following closed-head injury. *Journal of Clinical & Experimental Neuropsychology*, **12**, 703-714.
- HINTZMAN, D. (1990). *Permastore or grade inflation? Adjusting Bahrick's data for changes in academic standards* (Tech. Rep. No. 90-15). University of Oregon: Institute of Cognitive & Decision Sciences.
- HODGES, J. R. (1995). Retrograde amnesia. In A. D. Baddeley, B. A. Wilson, & F. N. Watts (Eds.), *Handbook of memory disorders* (pp. 81-107). Chichester, U.K.: Wiley.
- HORTON, D. L., & TURNAGE, T. W. (1976). *Human learning*. Englewood Cliffs, NJ: Prentice-Hall.
- HOUSTON, J. P. (1981). *Fundamentals of learning and memory*. New York: Academic Press.
- HUBER, S. J., SHUTTLEWORTH, E. C., & PAULSON, G. W. (1986). Dementia in Parkinson's disease. *Archives of Neurology*, **43**, 987-990.
- HULSE, S. H., DEESE, J., & EGERTH, H. (1975). *The psychology of learning*. New York: McGraw-Hill.
- HUNKIN, N. M., PARKIN, A. J., BRADLEY, V. A., BURROWS, E. H., ALDRICH, F. K., JANSARI, A., & BURDON-COOPER, C. (1995). Focal retrograde amnesia following closed head injury: A case study and theoretical account. *Neuropsychologia*, **33**, 509-523.
- ISAAC, C. L., HOLDSTOCK, J. S., CEZAYIRLI, E., ROBERTS, J. N., HOLMES, C. J., & MAYES, A. R. (1998). Amnesia in a patient with lesions limited to the dorsomedial thalamic nucleus. *Neurocase*, **4**, 497-508.
- JACKSON, H. F., & BENTALL, R. P. (1991). Operant conditioning in am-

- nestic subjects: Response patterning and sensitivity to schedule changes. *Neuropsychology*, **5**, 89-105.
- KAPUR, N. (1993). Focal retrograde amnesia in neurological disease: A critical review. *Cortex*, **29**, 217-234.
- KAPUR, N. (1999). Syndromes of retrograde amnesia: A conceptual and empirical synthesis. *Psychological Bulletin*, **125**, 800-825.
- KAPUR, N., & BROOKS, D. J. (1999). Temporally-specific retrograde amnesia in two cases of discrete bilateral hippocampal pathology. *Hippocampus*, **9**, 247-254.
- KAPUR, N., ELLISON, D., SMITH, M. P., McLELLAN, D. L., & BURROWS, E. H. (1992). Focal retrograde amnesia following bilateral temporal lobe pathology. *Brain*, **115**, 73-85.
- KAPUR, N., HEATH, P., MEUDELL, P., & KENNEDY, P. (1986). Amnesia can facilitate memory performance: Evidence from a patient with dissociated retrograde amnesia. *Neuropsychologia*, **24**, 215-221.
- KAPUR, N., SCHOLEY, K., MOORE, E., BARKER, S., BRICE, J., THOMPSON, S., SHIEL, A., CARN, R., ABBOTT, P., & FLEMING, J. (1996). Long-term retention deficits in two cases of disproportionate retrograde amnesia. *Journal of Cognitive Neuroscience*, **8**, 416-434.
- KAPUR, N., SCHOLEY, K., MOORE, E., BARKER, S., MAYES, A., BRICE, J., & FLEMING, J. (1994). The mammillary bodies revisited. In L. S. Ceramak (Ed.), *Neuropsychological explorations of memory and cognition: Essays in honor of Nelson Butters* (pp. 159-189). New York: Plenum.
- KAPUR, N., YOUNG, A., BATEMAN, D., & KENNEDY, P. (1989). Focal retrograde amnesia: A long term clinical and neuropsychological follow-up. *Cortex*, **25**, 387-402.
- KARNI, A., TANNE, D., RUBENSTIEN, B. S., ASKENASY, J. J. M., & SAGI, D. (1994). Dependence on REM sleep of overnight improvement of a perceptual skill. *Science*, **265**, 679-682.
- KARTSOUNIS, L. D., RUDGE, P., & STEVENS, J. M. (1995). Bilateral lesions of CA1 and CA2 fields of the hippocampus are sufficient to cause a severe amnesia syndrome in humans. *Journal of Neurology, Neurosurgery, & Psychiatry*, **59**, 95-98.
- KATZ, D. I., ALEXANDER, M. P., & MANDELL, A. M. (1987). Dementia following strokes in the mesencephalon and diencephalon. *Archives of Neurology*, **44**, 1127-1133.
- KELLER, R., & SHAYWITZ, B. A. (1986). Amnesia or fugue state: A diagnostic dilemma. *Developmental & Behavioral Pediatrics*, **7**, 131-132.
- KESSLER, J., MARKOWITSCH, H. J., HUBER, M., KALBE, E., WEBER-LUXEMBURGER, G., & KOCK, P. (1997). Massive and persistent anterograde amnesia in the absence of detectable brain damage: Anterograde psychogenic amnesia or gross reduction in sustained effort? *Journal of Clinical & Experimental Neuropsychology*, **19**, 604-614.
- KINTSCH, W. (1970). *Learning, memory, and conceptual processes*. New York: Wiley.
- KNOWLTON, B. J., & FANSELLOW, M. S. (1998). The hippocampus, consolidation and on-line memory. *Current Opinion in Neurobiology*, **8**, 293-296.
- KOPELMAN, M. D. (1989). Remote and autobiographical memory, temporal context memory and frontal atrophy in Korsakoff and Alzheimer patients. *Neuropsychologia*, **27**, 437-460.
- KOPELMAN, M. D., STANHOPE, N., & KINGSLY, D. (1999). Retrograde amnesia in patients with diencephalic, temporal lobe or frontal lesions. *Neuropsychologia*, **37**, 939-958.
- KOPELMAN, M. D., WILSON, B. A., & BADDELEY, A. D. (1989). The Autobiographical Memory Interview: A new assessment of autobiographical and personal semantic memory in amnesic patients. *Journal of Clinical & Experimental Psychology*, **11**, 724-744.
- KRITCHEVSKY, M., & SQUIRE, L. R. (1993). Permanent global amnesia with unknown etiology. *Neurology*, **43**, 326-332.
- LECHNER, H. A., SQUIRE, L. R., & BYRNE, J. H. (1999). 100 years of consolidation—remembering Müller and Pilzecker. *Learning & Memory*, **6**, 77-87.
- LEVIN, H. S., GROSSMAN, R. G., & KELLY, P. J. (1977). Assessment of long-term memory in brain-damaged patients. *Journal of Consulting & Clinical Psychology*, **45**, 684-688.
- LEVIN, H. S., HIGH, W. M., MEYERS, C. A., VON LAUFEN, A., HAYDEN, M. E., & EISENBERG, H. M. (1985). Impairment of remote memory after closed head injury. *Journal of Neurology, Neurosurgery, & Psychiatry*, **48**, 556-563.
- LEVIN, H. S., PETERS, B. H., & HULKONEN, D. A. (1983). Early concepts of anterograde and retrograde amnesia. *Cortex*, **19**, 427-440.
- MACKAY, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills*. New York: Springer-Verlag.
- MACKENZIE, S. J., & HODGES, J. R. (1997). Preservation of famous person knowledge in a patient with severe post anoxic amnesia. *Cortex*, **33**, 733-742.
- MACKINNON, D. F., & SQUIRE, L. R. (1989). Autobiographical memory and amnesia. *Psychobiology*, **17**, 247-256.
- MARAVITA, A., SPADONI, M., MAZZUCCHI, A., & PARMA, M. (1995). A new case of retrograde amnesia with abnormal forgetting rate. *Cortex*, **31**, 653-667.
- MARKOWITSCH, H. J., CALABRESE, P., LIESS, J., HAUPPTS, M., DURWEN, H. F., & GEHLEN, W. (1993). Retrograde amnesia after traumatic injury of the fronto-temporal cortex. *Journal of Neurology, Neurosurgery, & Psychiatry*, **56**, 988-992.
- MARKOWITSCH, H. J., & PRITZEL, M. (1985). The neuropathology of amnesia. *Progress in Neurobiology*, **25**, 189-287.
- MARKOWITSCH, H. J., VON CRAMON, Y., & SCHURI, U. (1993). Mnestic performance profile of a bilateral diencephalic infarct patient with preserved intelligence and severe amnesia disturbances. *Journal of Clinical & Experimental Neuropsychology*, **15**, 627-652.
- MARKOWITSCH, H. J., WEBER-LUXEMBURGER, G., EWALD, K., KESSLER, J., & HEISS, W. D. (1997). Patients with heart attacks are not valid models for medial temporal lobe amnesia: A neuropsychological and FDG-PET study with consequences for memory research. *European Journal of Neurology*, **4**, 178-184.
- MARSLEN-WILSON, W. D., & TEUBER, H. L. (1975). Memory for remote events in anterograde amnesia: Recognition of public figures from news photographs. *Neuropsychologia*, **13**, 347-352.
- MAYES, A. R. (1995). The assessment of memory disorders. In A. D. Baddeley, B. A. Wilson, & F. N. Watts (Eds.), *Handbook of memory disorders* (pp. 367-391). Chichester, UK.: Wiley.
- MAYES, A. R., DAUM, I., MARKOWITSCH, H. J., & SAUTER, B. (1997). The relationship between retrograde and anterograde amnesia in patients with typical global amnesia. *Cortex*, **33**, 197-217.
- MAYES, A. R., DOWNES, J. J., McDONALD, C., POOLE, V., ROOKE, S., SAGAR, H. J., & MEUDELL, P. R. (1994). Two tests for assessing remote public knowledge: A tool for assessing retrograde amnesia. *Memory*, **2**, 183-210.
- MAYES, A. R., MEUDELL, P. R., MANN, D., & PICKERING, A. (1988). Location of lesions in Korsakoff's syndrome: Neuropsychological and neuropathological data on two patients. *Cortex*, **24**, 367-388.
- MCCLELLAND, J. L., MCNAUGHTON, B. L., & O'REILLY, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, **102**, 419-437.
- MCDougall, W. (1901). Experimentelle Beiträge zur Lehre vom Gedächtnis: von G. E. Müller und A. Pilzecker. *Mind*, **10**, 388-394.
- MCGAUGH, J. L. (2000). Memory—a century of consolidation. *Science*, **287**, 248-251.
- MCGAUGH, J. L., & GOLD, P. E. (1976). Modulation of memory by electrical stimulation of the brain. In M. R. Rosenzweig & E. L. Bennett (Eds.), *Neural mechanisms of learning and memory* (pp. 549-560). Cambridge, MA: MIT Press.
- MEUDELL, P. R. (1992). Irrelevant, incidental and core features in the retrograde amnesia associated with Korsakoff's psychosis: A review. *Behavioural Neurology*, **5**, 67-74.
- MEUDELL, P. R., NORTHERN, B., SNOWDEN, J. S., & NEARY, D. (1980). Long-term memory for famous voices in amnesia and normal subjects. *Neuropsychologia*, **18**, 133-139.
- MILNER, B. (1959). The memory defect in bilateral hippocampal lesions. *Psychiatric Research Reports*, **11**, 43-52.
- MILNER, B. (1972). Disorders of learning and memory after temporal lobe lesions in man. *Clinical Neurosurgery*, **19**, 421-466.
- MONTALDI, D., & PARKIN, A. J. (1989). Retrograde amnesia in Korsakoff's syndrome: An experimental and theoretical analysis. In J. R. Crawford & D. M. Parker (Eds.), *Developments in clinical and experimental neuropsychology* (pp. 213-218). New York: Plenum.

- MORRIS, M. K., BOWERS, D. W., CHATTERJEE, A., & HEILMAN, K. M. (1992). Amnesia following a discrete basal forebrain lesion. *Brain*, **115**, 1827-1847.
- MOSCOVITCH, M., & NADEL, L. (1998). Consolidation and the hippocampal complex revisited: In defense of the multiple-trace model. *Current Opinion in Neurobiology*, **8**, 297-300.
- MÜLLER, G. E., & PILZECKER, A. (1900). Experimentelle Beiträge zur Lehre vom Gedächtnis. *Zeitschrift für Psychologie* (Suppl. 1).
- MURRE, J. M. J. (1996). TraceLink: A model of amnesia and consolidation of memory. *Hippocampus*, **6**, 675-684.
- NADEL, L., & MOSCOVITCH, M. (1997). Memory consolidation, retrograde amnesia and the hippocampal complex. *Current Opinion in Neurobiology*, **7**, 217-227.
- O'CONNOR, M., BUTTERS, N., Miliotis, P., ESLINGER, P., & CERMAK, L. S. (1992). The dissociation of anterograde and retrograde amnesia in a patient with herpes encephalitis. *Journal of Clinical & Experimental Neuropsychology*, **14**, 159-178.
- OGDEN, J. A., & CORKIN, S. (1991). Memories of H.M. In W. C. Abraham, M. C. Corballis, & K. G. White (Eds.), *Memory mechanisms: A tribute to G. V. Goddard* (pp. 195-215). Hillsdale, NJ: Erlbaum.
- PAPAGNO, C. (1998). Transient retrograde amnesia associated with impaired naming of living categories. *Cortex*, **34**, 111-121.
- PARKIN, A. J., & HUNKIN, N. M. (1991). Memory loss following radiotherapy for nasal pharyngeal carcinoma—an unusual presentation of amnesia. *British Journal of Clinical Psychology*, **30**, 349-357.
- PARKIN, A. J., MONTALDI, D., LENG, N. R. C., & HUNKIN, N. M. (1990). Contextual cueing effects in the remote memory of alcoholic Korsakoff patients and normal subjects. *Quarterly Journal of Experimental Psychology*, **42A**, 585-596.
- PARKIN, A. J., REES, J. E., HUNKIN, N. M., & ROSE, P. E. (1994). Impairment of memory following discrete thalamic infarction. *Neuropsychologia*, **32**, 39-51.
- PAUL, R. H., BLANCO, C. R., HAMES, K. A., & BEATTY, W. W. (1997). Autobiographical memory in multiple sclerosis. *Journal of the International Neuropsychological Society*, **3**, 246-251.
- POLSTER, M. R., NADEL, L., & SCHACTER, D. L. (1991). Cognitive neuroscience analyses of memory: A historical perspective. *Journal of Cognitive Neuroscience*, **3**, 95-116.
- REED, J. M., & SQUIRE, L. R. (1998). Retrograde amnesia for facts and events: Findings from four new cases. *Journal of Neuroscience*, **18**, 3943-3954.
- REINVANG, I., & GJERSTAD, L. (1998). Focal retrograde amnesia associated with vascular headache. *Neuropsychologia*, **36**, 1335-1341.
- REMPEL-CLOWER, N. L., ZOLA, S. M., SQUIRE, L. R., & AMARAL, D. G. (1996). Three cases of enduring memory impairment after bilateral damage limited to the hippocampal formation. *Journal of Neuroscience*, **16**, 5233-5255.
- RIBOT, T. (1882). *Diseases of memory*. London: Kegan Paul, Trench & Co.
- RICCIO, D. C., & RICHARDSON, R. (1984). The status of memory following experimentally induced amnesias: Gone, but not forgotten. *Physiological Psychology*, **12**, 59-72.
- ROSE, F. C., & SYMONDS, C. P. (1960). Persistent memory defect following encephalitis. *Brain*, **83**, 195-212.
- RUSSELL, W. R., & NATHAN, P. W. (1946). Traumatic amnesia. *Brain*, **69**, 280-300.
- SAGAR, H., COHEN, N. J., SULLIVAN, E. V., CORKIN, S., & GROWDON, J. H. (1988). Remote memory function in Alzheimer's disease and Parkinson's disease. *Brain*, **111**, 185-206.
- SALMON, D. P., LASKER, B. R., BUTTERS, N., & BEATTY, W. W. (1988). Remote memory in a patient with circumscribed amnesia. *Brain & Cognition*, **7**, 201-211.
- SANDERS, H. I., & WARRINGTON, E. K. (1971). Memory for remote events in amnesic patients. *Brain*, **94**, 661-668.
- SANDERS, H. I., & WARRINGTON, E. K. (1975). Retrograde amnesia in organic amnesic patients. *Cortex*, **11**, 397-400.
- SCHACTER, D. L. (1996). *Searching for memory: The brain, the mind, and the past*. New York: Basic Books.
- SCHACTER, D. L., & KIHLSTROM, J. F. (1989). Functional amnesia. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (Vol. 3, pp. 209-231). New York: Elsevier.
- SCHMIDT, H. G., PEECK, V. H., PAAS, F., & VAN BREUKELLEN, G. J. P. (2000). Remembering the street names of one's childhood neighbourhood: A study of very long-term retention. *Memory*, **8**, 37-49.
- SCHMIDTKE, K., & VÖLLMER, H. (1997). Retrograde amnesia: A study of its relation to anterograde amnesia and semantic memory deficits. *Neuropsychologia*, **35**, 505-518.
- SCHNIDER, A., REGARD, M., & LANDIS, T. (1994). Anterograde and retrograde amnesia following bitemporal infarction. *Behavioural Neurology*, **7**, 87-92.
- SELTZER, B., & BENSON, D. F. (1974). The temporal pattern of retrograde amnesia in Korsakoff's disease. *Neurology*, **24**, 527-530.
- SHIFFRIN, R. M., & ATKINSON, R. C. (1969). Storage and retrieval processes in long-term memory. *Psychological Review*, **76**, 179-193.
- SHIMAMURA, A., & SQUIRE, L. R. (1986). Korsakoff's syndrome: A study of the relation between anterograde amnesia and remote memory impairment. *Behavioral Neuroscience*, **100**, 165-170.
- SIEGERT, R. J., & WARRINGTON, E. K. (1996). Spared retrograde memory with anterograde amnesia and widespread cognitive deficits. *Cortex*, **32**, 177-185.
- SNOW, W. G. (1992). The Toronto Television Test: A pilot study of a new test of remote memory [Abstract]. *Journal of Clinical & Experimental Neuropsychology*, **14**, 46.
- SPORNS, O., & TONONI, G. (1994). *Selectionism and the brain*. San Diego: Academic Press.
- SQUIRE, L. R. (1986). Mechanisms of memory. *Science*, **232**, 1612-1619.
- SQUIRE, L. R. (1987). *Memory and brain*. New York: Oxford University Press.
- SQUIRE, L. R. (1989). Mechanisms of memory. In K. L. Kelner & D. E. Koshland (Eds.), *Molecules to models: Advances in neuroscience* (pp. 500-515). Washington, DC: American Association for the Advancement of Science.
- SQUIRE, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, **99**, 195-231.
- SQUIRE, L. R., & ALVAREZ, P. (1995). Retrograde amnesia and memory consolidation: A neurobiological perspective. *Current Opinion in Neurobiology*, **5**, 169-177.
- SQUIRE, L. R., CLARK, R. E., & KNOWLTON, B. J. (2001). Retrograde amnesia. *Hippocampus*, **11**, 50-55.
- SQUIRE, L. R., & COHEN, N. (1979). Memory and amnesia: Resistance to disruption develops for years after learning. *Behavioural & Neural Biology*, **25**, 115-125.
- SQUIRE, L. R., & COHEN, N. J. (1982). Remote memory, retrograde amnesia, and the neuropsychology of memory. In L. S. Cermak (Ed.), *Human memory and amnesia* (pp. 275-303). Hillsdale, NJ: Erlbaum.
- SQUIRE, L. R., COHEN, N. J., & NADEL, L. (1984). The medial temporal region and memory consolidation: A new hypothesis. In H. Weintraub & E. S. Parker (Eds.), *Memory consolidation* (pp. 185-210). Hillsdale, NJ: Erlbaum.
- SQUIRE, L. R., HAIST, F., & SHIMAMURA, A. P. (1989). The neurology of memory: Quantitative assessment of retrograde amnesia in two groups of amnesic patients. *Journal of Neuroscience*, **9**, 828-839.
- SQUIRE, L. R., KNOWLTON, B., & MUSEN, G. (1993). The structure and organization of memory. *Annual Review of Psychology*, **44**, 453-495.
- SQUIRE, L. R., & SLATER, P. C. (1975). Forgetting in very long-term memory as assessed by an improved questionnaire technique. *Journal of Experimental Psychology: Human Learning & Memory*, **1**, 50-54.
- SQUIRE, L. R., & SLATER, P. C. (1978). Anterograde and retrograde memory impairment in chronic amnesia. *Neuropsychologia*, **16**, 313-322.
- SQUIRE, L. R., ZOLA-MORGAN, S., CAVE, C. B., HAIST, F., MUSEN, G., & SUZUKI, W. A. (1990). Memory: Organization of brain systems and cognition. In D. E. Meyer & S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (pp. 393-424). Cambridge, MA: MIT Press.
- STERN, L. (1985). *The structures and strategies of human memory*. Homewood, IL: Dorsey.
- STEVENS, M. (1979). Famous Personality Test: A test for measuring remote memory. *Bulletin of the British Psychological Society*, **32**, 211.
- STUSS, D., GUBERMAN, A., NELSON, R., & LAROCHELLE, S. (1988). The neuropsychology of paramedian thalamic infarction. *Brain & Cognition*, **8**, 348-378.
- STUSS, D., & GUZMAN, A. (1988). Severe remote memory loss with min-

- imal anterograde amnesia: A clinical note. *Brain & Cognition*, **8**, 21-30.
- TANAKA, Y., MIYAZAWA, Y., HASHIMOTO, R., NAKANO, I., & OBAYASHI, T. (1999). Postencephalitic focal retrograde amnesia after bilateral anterior temporal lobe damage. *Neurology*, **53**, 344-350.
- TEYLER, T. L., & DiSCENNA, P. (1986). The hippocampal memory indexing theory. *Behavioral Neuroscience*, **100**, 147-154.
- TREATWAY, M., MCCLOSKEY, M., GORDON, B., & COHEN, N. J. (1992). Landmark life events and the organization of memory: Evidence from functional retrograde amnesia. In S. Christianson (Ed.), *The handbook of emotion and memory: Research and theory* (pp. 389-410). Hillsdale, NJ: Erlbaum.
- TREVES, A., & ROLLS, E. T. (1994). Computational analysis of the role of the hippocampus in memory. *Hippocampus*, **4**, 374-391.
- TULVING, E., SCHACTER, D. L., McLACHLAN, D. R., & MOSCOVITCH, M. (1988). Priming of semantic autobiographical knowledge: A case study of retrograde amnesia. *Brain & Cognition*, **7**, 3-20.
- VENNARI, A., NICHELLI, P., MODONESI, G., MOLINARI, M. A., RUSSO, R., & SARDINI, C. (1997). Impairment in dating and retrieving remote events in patients with early Parkinson's disease. *Journal of Neurology, Neurosurgery, & Psychiatry*, **62**, 410-413.
- VERFAELLIE, M., REISS, L., & ROTH, H. L. (1995). Knowledge of new English vocabulary in amnesia: An examination of premorbidly acquired semantic memory. *Journal of the International Neuropsychological Society*, **1**, 443-453.
- WESTMACOTT, R., LEACH, L., FREEDMAN, M., & MOSCOVITCH, M. (2001). Different patterns of autobiographical memory loss in semantic dementia and medial temporal lobe amnesia: A challenge to consolidation theory. *Neurocase*, **7**, 37-55.
- WHEATLEY, J., & MCGRATH, J. (1997). Co-occurrence of executive impairment and amnesic syndrome following sub-arachnoid haemorrhage: A case study. *Cortex*, **33**, 711-721.
- WICKELGREN, W. A. (1974). Single-trace fragility theory of memory dynamics. *Memory & Cognition*, **2**, 775-780.
- WICKELGREN, W. A. (1977). *Learning and memory*. Englewood Cliffs, NJ: Prentice-Hall.
- WICKELGREN, W. A. (1979). Chunking and consolidation: A theoretical synthesis of semantic networks, configuring, S-R versus cognitive learning, normal forgetting, the amnesic syndrome, and the hippocampal arousal system. *Psychological Review*, **86**, 44-60.
- WILLIAMS, M., & SMITH, H. V. (1954). Mental disturbances in tuberculosis meningitis. *Journal of Neurology, Neurosurgery, & Psychiatry*, **17**, 173-182.
- WILLIAMS, M., & ZANGWILL, O. L. (1952). Retrograde amnesia following head injury. *Journal of Neurology, Neurosurgery, & Psychiatry*, **15**, 54-61.
- WILSON, B. (1987). Identification and remediation of everyday problems in memory-impaired patients. In O. A. Parsons, N. Butters, & P. E. Nathan (Eds.), *Neuropsychology of alcoholism: Implications for diagnosis and treatment* (pp. 322-338). New York: Guilford.
- WILSON, R., KASZNIK, A. W., & FOX, J. H. (1981). Remote memory in senile dementia. *Cortex*, **17**, 41-48.
- WINOCUR, G., OXBURY, S., ROBERTS, R., AGNETTI, V., & DAVIS, C. (1984). Amnesia in a patient with bilateral lesions to the thalamus. *Neuropsychologia*, **22**, 123-143.
- WINSON, J. (1985). *Brain and psyche*. Garden City, NJ: Doubleday.
- ZECHMEISTER, E. B., & NYBERG, S. E. (1982). *Human memory*. Monterey, CA: Brooks/Cole.

APPENDIX

Types of Tests Used in the Evaluation of RA Function

Persons

Faces. Albert, Butters, & Levin (1979); Graff-Radford, Eslinger, Damasio, & Yamada (1984); Markowitsch, Calabrese, et al. (1993); Marslen-Wilson & Teuber (1975); Parkin, Montaldi, Leng, & Hunkin (1990); Squire & Cohen (1982).

Names. Gabrieli, Cohen, & Corkin (1988); Kapur, Young, Bateman, & Kennedy (1989); Mayes et al. (1994); Montaldi & Parkin (1989); Squire et al. (1990); Stevens (1979).

Voices. Meudell, Northern, Snowden, & Neary (1980).

Events

Current events. Albert et al. (1979); Gade & Mortensen (1990); Goldberg & Barnett (1985); Grossi, Trojano, Grasso, & Orsini (1988); Kopelman (1989); Mayes et al. (1994); O'Connor, Butters, Miliotis, Eslinger, & Cermak (1992); Parkin & Hunkin (1991); Seltzer & Benson (1974); Squire & Cohen (1982); Squire, Haist, & Shimamura (1989); Squire & Slater (1978); Stuss, Guberman, Nelson, & Larochelle (1988); Stuss & Guzman (1988).

Oscar awards. Brandt & Benedict (1993).

Famous scenes. Kopelman, Wilson, & Baddeley (1989).

Retail prices. B. Wilson (1987).

Television programs. Snow (1992); Squire & Slater (1975).

Semantic Information

Maps. Beatty (1988); De Renzi, Liotti, & Nichelli (1987).

General knowledge. Goldberg & Bilder (1986).

Word meanings. Verfaellie, Reiss, & Roth (1995).

Professional knowledge. Beatty, Salmon, Bernstein, & Butters (1987); Butters & Cermak (1986).
