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Semantic Memory Content in Permastore: Fifty Years of Memory for Spanish Learned in School

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Retention of Spanish learned in school was tested over a 50-year period for 733 individuals. Tests of reading comprehension, recall, and recognition vocabulary and grammar were administered together with a questionnaire to determine the level of original training, the grades received, and rehearsals during the retention interval in the form of reading, writing, speaking, or listening to Spanish. Multiple regression analysis shows that retention throughout the 50-year period is predictable on the basis of the level of original training. The great majority of subjects rehearse so little that the data reveal no significant rehearsal effects. The analysis yields memory curves which decline exponentially for the first 3–6 years of the retention interval. After that retention remains unchanged for periods of up to 30 years before showing a final decline. Large portions of the originally acquired information remain accessible for over 50 years in spite of the fact the information is not used or rehearsed. This portion of the information in a "permastore" state is a function of the level of original training, the grades received in Spanish courses, and the method of testing (recall vs. recognition), but it appears to be unaffected by ordinary conditions of interference. The life-span frequency distribution of learned responses is discontinuous; one portion of the response distribution has life spans of 0–6 years, the other portion, life spans in excess of 25 years, and no responses have life spans of 6–25 years. This suggests a discrete transition into a permastore state during the extended period of original training. Analysis of successive relearning processes over extended time periods is deemed essential for an understanding of the acquisition of permanent semantic memory content.

Acquisition of knowledge is the objective of education, and the organization and acquisition of semantic knowledge have been important foci of psychological research. In contrast, questions concerned with the permanence of knowledge have been neglected. It is clear that much of the knowledge acquired in schools is eventually lost, but we have failed to investigate these losses systematically, and hence we know little about how they are affected by conditions of original learning or of later rehearsals. A few investigators have established how much is forgotten during the period immediately following learning (Cohen, 1976; Smythe, Jutras, Bramwell, and Gardner, 1973; Spitzer, 1939) but such research has never been extended to cover significant portions of the human life span. This dearth of information is reflected in textbooks concerned with memory. The leading texts, for example, Baddeley (1976), Wickelgren (1977), Klatzky (1980), Zechmeister and Nyberg (1982), and Ellis and Hunt (1983), give extensive coverage to losses of episodic memory

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content and to questions regarding the organization of semantic content, but they include no information about the long-term retention of semantic memory content. Neisser (1978) comments critically that higher education

> depends heavily on the assumption that students remember something valuable from their educational experience. One might expect psychologists to leap at the opportunity to study a critical memory problem so close at hand, but they never do. It is difficult to find even a single study, ancient or modern, of what is retained from academic instruction. Given our expertise and the way we earn our livings, this omission can only be described as scandalous! (p. 5)

The reasons for this neglect are methodological. Dependable conclusions regarding the loss of memory content require accurate assessments of the level of original knowledge and of rehearsals during the retention interval, and it is difficult to obtain such assessments in naturalistic memory research covering long time spans. Furthermore, conditions of learning and of rehearsals tend to change during long time periods, making it even more difficult to establish how much information has been lost. To overcome these problems a method of cross-sectional adjustment was applied in two previous investigations (Bahrick, 1983; Bahrick, Bahrick, and Wittlinger, 1975) that dealt, respectively, with retention of names and faces of high school classmates, and retention of the cognitive map of a city. The merits and shortcomings of this method have been discussed elsewhere, (Bahrick, 1979; Bahrick & Karis, 1982) and will be reviewed in later sections of this article. The present study deals with acquisition and retention of knowledge of Spanish learned in high school or college. The content is naturalistic and semantic in the sense that it is learned in real life and over a prolonged period, but unlike the two preceding investigations the content is acquired through study and rehearsal rather than as the incidental by-product of interacting with peers or with the spatial environment. For this reason the present research has direct implications for the technology of teaching and learning and for questions concerned with what I have called the maintenance of knowledge.

The purpose of this investigation was twofold: (a) to provide normative data regarding long-term retention of this semantic memory content, and (b) to project estimates of the types and amounts of periodic rehearsal needed to maintain various levels of performance (Bahrick, 1979). The investigation fails to accomplish the second goal because the subjects of this research rehearsed their acquired knowledge so little that the data reveal no significant rehearsal effects. This failure turns out to be fortuitous because it leads to significant conclusions regarding the semipermanent nature of unrehearsed knowledge, and to important inferences regarding previously undocumented characteristics of the memory system. A method of transforming retention curves into life-span frequency distributions of responses reveals that this memory content has a dichotomous life-span distribution. One portion of the content is lost in accordance with an exponential decay function within 6 years after learning terminates. The other portion survives more than 25 years, and most of that content has a life span of more than 50 years. The implications are that during an extended acquisition period, portions of the long-term memory content acquire a semipermanent character. This content is maintained indefinitely without rehearsals, and is immune to ordinary interference effects. Understanding the circumstances of this transformation is critical for an understanding of long-term memory and for advances in the technology of education.

Method

Subject Characteristics and Recruitment Procedures

There were 773 participants in the study. Of these, 146 were students who at the time of testing were enrolled in a high school- or college-level Spanish course, or who had recently completed such a course. The tests were administered during the last week of course attendance, or within 2 months thereafter. A total of 587 individuals had taken one or more Spanish courses during their attendance at high school or college, and their Spanish instruction had occurred from 1 to 50 years prior to being tested. These subjects were assigned to one of eight groups in accordance with the time elapsed since their last Spanish course. The remaining 40 individuals had no instruction in Spanish. They were included in the study in order to establish a baseline for performance that differentiates knowledge acquired in Spanish classes from knowledge acquired incidentally, as well as from correct answers based upon guessing. Twenty of these individuals (C1) ranged in age from 17 to 22 and their performance provides a control for

individuals currently enrolled in Spanish classes. The other 20 (C2) ranged in age from 41 to 62 (M = 51), and their performance provides a control for the inference of long-term memory from Spanish instruction.

The mean of the retention interval, and the level of Spanish training for the eight retention groups are presented in Table 1. For purposes of this classification and subsequent data analyses, a full year of high school Spanish instruction is equated with a term or semester course in college. Thus individuals classified at Level 3 in Table 1 include those who took three college courses of Spanish and no high school courses, as well as those with three years of high school Spanish instruction and no college courses. Subjects with a combination of high school and college instruction were assigned to a level determined by the highest level college course taken, regardless of the amount of prior high school instruction. Thus subjects who completed 2 years of Spanish in high school and followed this by taking two courses in college, were assigned to Level 2 if the college courses were beginning Spanish, but to Level 4 if the two college courses were intermediate Spanish. The decision to equate high school and college instruction in this way was based on data available from college language placement examinations. Students with high school language instruction are typically assigned to an appropriate level college course on the basis of their performance on a placement examination. Separate analyses of knowledge acquired in high school and college were not carried out because most subjects had taken courses at both the high school and college level.

Students enrolled in Spanish courses at the time of testing were recruited from Ohio Wesleyan University; Hayes High School in Delaware, Ohio; and The Ohio State University. Some Ohio Wesleyan University students satisfied a course requirement in introductory psychology by taking the test; the remaining subjects were paid. Subjects not enrolled in Spanish courses were recruited by newspaper advertisement and with the help of local churches and community service organizations. Most of these subjects were volunteers who donated their pay to the service organization that helped to recruit them. The control subjects (C1 and C2) were tested 2 years after the other subjects. They were recruited by the same methods and from the same populations as the remaining subjects.

Test Construction and Administration

In addition to taking a test of knowledge of Spanish, subjects completed a questionnaire designed to provide information about Spanish instruction; grades obtained in Spanish courses; and various opportunities to read, write, speak, or listen to Spanish and other Romance languages during the retention interval. Each subject supplied the dates of these experiences and signed a statement authorizing the high school or college attended to release information concerning the grades earned in Spanish courses. A summary of the questionnaire and portions of each subtest appear in Appendixes A and B. The test consists of the following 10 subtests: Reading comprehension; Spanish–English recall vocabulary; Spanish–English recognition vocabulary; English–Spanish recall vocabulary; English–Spanish recognition vocabulary; grammar recall; grammar recognition; idiom recall; idiom recognition; and word order. The decision to develop a test for the purpose of this study was reached after consideration of existing language tests indicated that available tests, for example, the CLOZE tests, were reliable (Oller, 1973) but would not yield the subscores desired for obtaining analytic learning and memory data. The subtests were constructed in such a way as to minimize "built in" interdependence. Thus the meaning of all words was supplied in subtests measuring knowledge of grammar, idioms, and word order, and the sequence of subtests was arranged in such a way as to minimize facilitation effects among the subtests. The tests were assembled on the basis of vocabulary lists and reading exercises available in textbooks or contributed by language teachers. The test was revised several times on the basis of pilot data, so as to achieve a difficulty level suitable for reflecting improvement throughout a sequence of four college-level Spanish courses, and a total length that would permit completion of both the test and questionnaire within 1 hour.

The test was administered to individuals or groups of up to 40 subjects, without strict adherence to time limits. Most individuals completed test and questionnaire within 1 hour, but they were allowed to continue as long as they chose. The decision not to impose time limits was based on the fact that the concern of this investigation is the amount of knowledge retained rather than the speed of

Table 1
Number of Subjects at Each Level of Training

Group	Mean interval (months)	Training level									
		1	2	3	4	5	6	7	8	9	10
Current students	0.1	52	27	39	18	3	2	0	0	0	5
1	14.5	12	26	34	53	0	2	1	0	0	2
2	37.8	15	61	21	11	0	2	0	0	0	0
3	69.1	27	36	15	23	2	4	0	3	0	2
4	114.0	5	16	8	11	2	3	0	0	0	2
5	175.1	11	6	10	11	2	1	0	0	1	3
6	300.6	4	32	4	10	2	5	0	2	0	2
7	415.2	6	23	7	10	1	0	0	1	0	1
8	596.4	1	16	4	6	0	3	0	2	1	0

retrieval. Subjects ranged in age from 17 to over 70 years, and adherence to strict time limits could have adversely affected the performance of older subjects (Burke & Light, 1981).

Verification of Questionnaire Data

It is important to determine the accuracy of information given on the questionnaire since the independent variables in this investigation are derived by scoring answers provided on the questionnaire. To determine the extent to which these data are subject to error because of faulty memory or other causes, we verified answers regarding the number of Spanish courses taken, the time elapsed since the last Spanish course, and the grades received in Spanish courses. This was done for 14% of the subjects, selected on the basis of accessibility of the data. The verification was obtained by checking answers against the records of the registrar at Ohio Wesleyan University and at The Ohio State University. Although the selection of data for verification was not random, subjects belonging to the various retention intervals were represented proportionately in the verified data, and the results can be generalized with confidence to the remaining subjects.

Verification of the number of Spanish courses taken showed that 81% of all subjects reported the number accurately. Subjects belonging to Time Groups 1 and 2 reported no errors; after that the error rate remained constant at 22%. Most errors were errors of one course, and subjects were twice as likely to understate the number of Spanish courses taken than to overstate that number. Verification of the retention interval reported by subjects indicated that 57% of all subjects stated the interval correctly, 89% reported an interval which fell within 10% of the correct interval, and 96% of subjects reported an interval which placed them within the same group to which they were assigned on the basis of the verified interval. Those subjects who committed errors were somewhat more likely to report an interval shorter than the verified interval, and the average error increased approximately proportionately to the retention interval.

Verification of reported grades showed that 78% were reported correctly, 97% reported average grades within 0.5 of the verified average. These data showed no systematic variation with the retention interval. Of those subjects who reported erroneously, a somewhat larger amount overstated their grades, and the average error of overstatement was twice as large as the average understatement (0.54 vs. 0.27). Thus, in contrast to memory of the retention interval, the accuracy of memory reports of grades does not decline with time. In a sense these data provide a study within a study; that is, they constitute a miniature study of the accuracy of reports based on long-term memory. These data are also of some general interest as they give an indication of the validity of other nonverified autobiographical memory reports here and elsewhere.

Scoring of Questionnaire Data

All of the variables entered into the analysis of data are presented in Table 2. Variables 1–10 are the dependent variables based on the scores obtained from the 10 subtests. Variables 11–42 are independent variables based on information taken from the questionnaire. The time elapsed between completion of the last Spanish course and the date of the test was calculated to the nearest month, and the assignment to groups was based upon this score. The level of Spanish training was established as reported earlier. Letter grades on all Spanish courses were converted into the conventional scale with A = 4; B = 3, and so forth, and an average grade was computed for each subject. Travel to Spanish-speaking countries was scored in terms of frequency, duration, and recency of trips. Frequency was scored in terms of the number of separate trips, regardless of duration. Duration was scored in terms of the aggregate number of days spent in Spanish-speaking countries, and recency, in terms of the number of months elapsed since the most recent trip. Separate subscores for these three variables were established for travel in the company of English-speaking people, and travel in which most or all conversation was in the Spanish language. Individuals who spent more than 1 year traveling in Spanish-speaking countries were excluded from the study as were those who reported extensive childhood experiences with the Spanish language based either on being raised in a Spanish-speaking home, prolonged residence in a Spanish-speaking country, or in a foreign-language elementary school program. The data regarding rehearsals during the retention interval in the form of listening to, reading, speaking, or writing in Spanish were scored by estimating the number of minutes per year spent in each category of activity. Separate scores were entered for the various subcategories, for example, reading newspapers, magazines, listening to TV, and so forth. To transform the frequency data of the questionnaire into estimates of minutes of rehearsal per year it was necessary to assign estimates of mean frequency to each frequency category. The category "once a year or less" was scored 0 or 1 depending on whether or not a duration of rehearsal was indicated. The frequency category of "2–11 times per year" was scored 6, the category "several times each month" was scored 30, and the category "several times each week" was scored 150. These estimated frequency-per-year scores were then multipled by the indicated average duration of the rehearsal activity to arrive at the estimated aggregate number of minutes per year spent in the activity.

The level of training in other Romance languages was scored in terms of the total number of courses taken in high school and college, using the same method of combining high school and college work as was used in determining the level of Spanish training.

Scoring the Language Test

Although the test is objective, a variety of scoring problems arose in regard to answers that were nearly correct or partly correct. These problems were most challenging in the reading comprehension subtest, but also occurred in tests of recall vocabulary. Two college teachers of Spanish examined pilot data and classified answers into the categories of correct, partly correct, and wrong. Guidelines for classifying answers to each question were established on the basis of agreement between the raters, and of dictionary definitions for individual words. The answers of *boyfriend, lover,* or *fiancee,* for example, were classified as a correct translation of the Spanish word *novio,* but the

answer of *girlfriend* was classified as partly correct. In order to avoid fractional scores, the subtests in which partial credit was to be awarded were scored on the basis of 2 points for correct answers and 1 point for answers that were partly correct, yielding a maximum score of twice the number of questions in the subtest. This scoring applied to the reading comprehension test yielded a maximum score of 40, and applied to subtests for recall of vocabulary and grammar yielded maximum scores of 30 points. No such ambiguities were present in the scoring of recognition tests, where the maximum score remained equal to the number of items on the test. Some subjects failed to answer individual questions on the five alternative recognition subtests in spite of instructions that encouraged guessing. In order to establish comparability of scores with those who received the benefits of guessing, unanswered recognition questions were awarded $\frac{1}{5}$ point. The fractional points were summed for each subtest, and a correction was made if the aggregate point score could be rounded to a whole number. Thus subjects who omitted the answers to 3–7 questions on a recognition subtest were awarded 1 additional point.

Data Analysis and Results

Acquisition Data

Means for all dependent variables for students at each level of Spanish instruction are shown in Table 3, along with the means for the control subjects C1 who had no Spanish instruction. Acquisition functions for the 10 dependent variables appear in Figures 1 and 2. The control subjects C1 provide the data for the initial points for all subtests. The data for plotting Figures 1 and 2 were obtained by dividing the mean raw score for each subtest by the maximum obtainable score on that subtest, and multiplying the quotient by 100. This yields a percentage score that permits certain comparisons. Subjects at Level 5 of Spanish instruction were grouped with those

Table 2
Abbreviations and Names of All Variables

Abbreviation	Variable	Abbreviation	Variable
PARCOM	(1) Reading comprehension	RECENG	Recency of visits using English in months
VSEREC	(2a) Vocabulary Spanish–English recall	RECSP	Recency of visits using Spanish in months
VSEREG	(2b) Vocabulary Spanish–English recognition	LSTRAD	Listening to radio (minutes per year)
VESREC	(2c) Vocabulary English–Spanish recall	LSTTV	Listening to television (minutes per year)
VESREG	(2d) Vocabulary English–Spanish recognition	LSTFLM	Listening to films (minutes per year)
GRMREC	(3a) Grammar recall	LSTCNV	Listening to conversation (minutes per year)
GRMREG	(3b) Grammar recognition	READNW	Reading of newspapers (minutes per year)
IDREC	(4a) Idiom recall	READMG	Reading of magazines (minutes per year)
IDREG	(4b) Idiom recognition	READBK	Reading of books (minutes per year)
WRDORD	(5) Word order	READCR	Reading of correspondence (minutes per year)
RETENT	Retention interval in months	SPEAK	Speaking (minutes per year)
LEVEL	Highest level of courses	WRITE	Writing (minutes per year)
HIGH	Level of high school courses	TOTLST	Total listening (minutes per year)
COLLEG	Level of college courses	TOTRED	Total reading (minutes per year)
TAPE	Level of courses using tapes	TOTROM	Total of Romance language courses
MEAN	Mean grade in courses	FRENCH	Level of French courses
GRDREC	Most recent grade	PORT	Level of Portuguese courses
TRVLEG	Travel using English (1 = yes, 0 = no)	ITALAN	Level of Italian courses
TRVLSP	Travel using Spanish (1 = yes, 0 = no)	LATIN	Level of Latin courses
FREQEG	Frequency of visits using English		
FREQSP	Frequency of visits using Spanish		
DURENG	Duration of visits using English in days		
DURSP	Duration of visits using Spanish in days		

Table 3
Subtest Performance by Students at Various Training Levels

Variable	Level of training						Possible score
	C1	1	2	3	4	8.3	
PARCOM	2.1	14.7	24.9	25.2	29.6	34.3	40
VSEREC	0.3	7.3	17.0	17.2	18.0	28.2	30
VSEREG	3.3	6.5	8.2	9.3	10.2	13.6	15
VESREC	0.3	12.7	22.0	19.8	23.1	29.3	30
VESREG	4.8	7.0	10.2	10.3	10.9	13.9	15
GRMREC	0.0	11.8	17.7	17.2	14.0	22.8	30
GRMREG	2.6	4.6	8.4	8.4	7.5	13.0	15
IDREC	0.0	1.9	2.9	3.6	3.2	6.7	10
IDREG	1.3	3.7	5.6	5.8	6.0	8.0	10
WRDORD	0.3	3.1	5.1	4.8	5.0	5.6	8

Note. See Table 2 for explanation of abbreviations.

at higher levels of training, because the number of subjects per group was too small to yield reliable data. The average training level for these subjects (8.3) is used in Table 3 and Figures 1 and 2. The test remains reasonably sensitive to continued improvement, and ceiling effects have little influence on performance at least through Training Level 4. Direct comparisons of recall and recognition performance are not appropriate since the words used for recall and recognition subtests are not the same. The difficulty level of each subtest was adjusted on the basis of pilot data so as to remain sensitive to improvements throughout the acquisition period. It is appropriate, however, to compare relative progress at various stages of training among the subtests. It is apparent, for instance, that the recall for the English equivalents of Spanish words is relatively low at Training Level 1, but for students at Training Level 8, performance on this subtest is high. In other words this subtest is not gen-

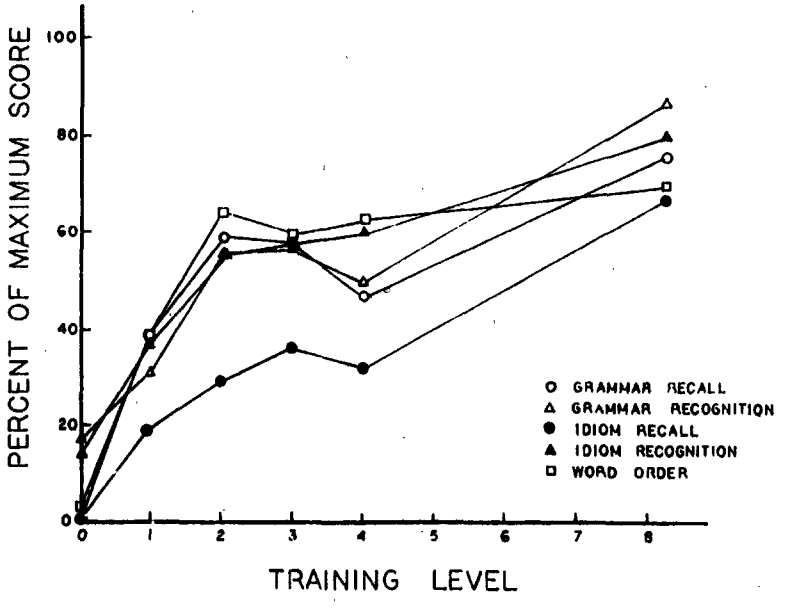

Figure 1. Learning curves for grammar, idioms, and word order.

erally more difficult than the other subtests; it is relatively difficult during the early stages of learning the language, but not during the later stages. The subtest for English recall for the meaning of Spanish idioms, on the other hand, is a relatively difficult test, that is, performance on this test remains lower than performance on the other tests throughout the learning period. It must be noted that the groups at various levels of training are not equated in regard to independent variables, and the values of Figures 1 and 2 are influenced by such inequalities. Thus subjects at Level 1 achieved a mean grade of 2.8 in Spanish whereas subjects at Level 8 achieved a mean grade of 3.5. No statistical adjustments were made to correct this inequality because the grading patterns in beginning courses differ from those in advanced courses. This difference may reflect general leniency of the instructor, and/or subject characteristics resulting from self-selection on the part of those individuals who chose to take advanced courses. However, these methodological problems do not directly apply to the retention data, permitting more sophisticated statistical treatment of the latter.

Retention Data

The mean scores on all variables for the eight retention groups and for the control group C2 appear in Table 4. It is apparent that the eight retention groups differ considerably on several independent variables likely to affect the amount of knowledge of Spanish. Training level varies from 2.3 for Group 2 to 3.6 for Group 5, and the level of training in other Romance languages varies from 0.7 to 2.7, with the older alumni groups generally having more training than the younger groups. To obtain estimates of retention which are free of these inequities, it is necessary to adjust the data. Two procedures were used to obtain the adjusted estimates. The first of these regression procedures closely follows the one used in the earlier investigations (Bahrick, 1983; Bahrick, et al., 1975). In this method of adjustment the data for all retention groups (excluding C2) are pooled and intercorrela-

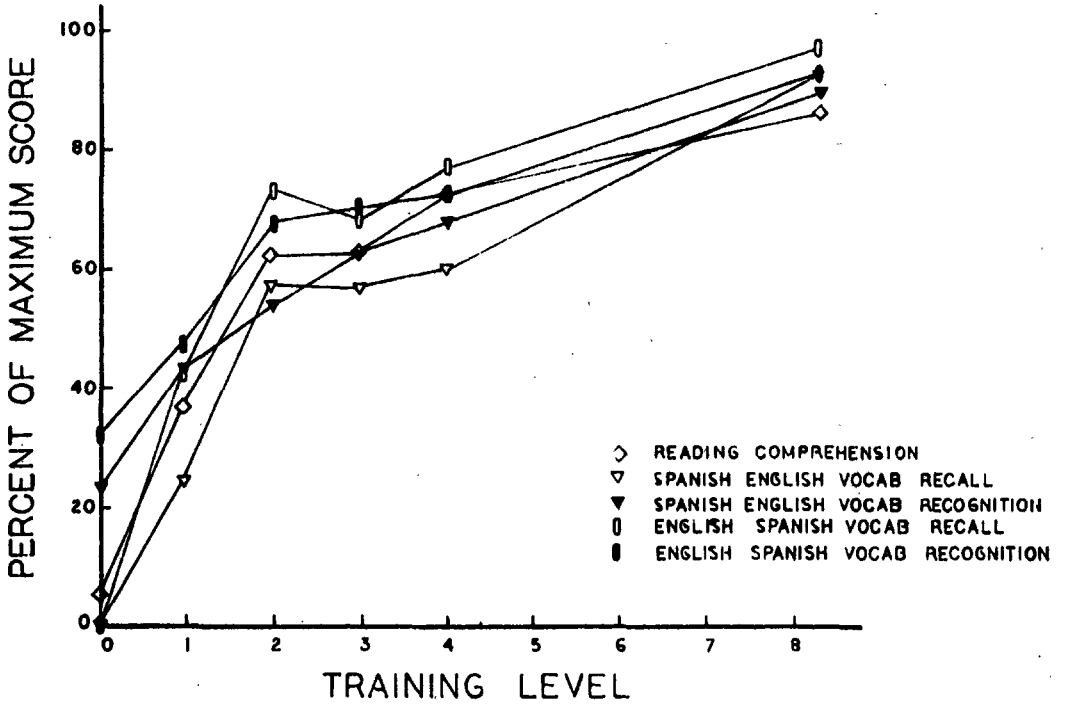

Figure 2. Learning curves for recall and recognition vocabulary and reading comprehension.

tions are established among all variables, with indicator variables designating time groups (Neter & Wasserman, 1974). Variables are then entered into the regression program in accordance with some fixed order, for example, the magnitude of the correlation with the dependent variable, and they are maintained in the regression equation if they add significantly to the portion of variance accounted for on the dependent variable. This approach yields common partial regression coefficients for the regression equations applicable to all time groups, and separate intercept values for the equation of each group. The adjusted scores are calculated for each group by multiplying the partial regression coefficient of each included variable by the desired value of that variable for the projected retention estimate.

Table 4
Unadjusted Mean Scores for Nine Groups

	Group								
Variable	1	2	3	4	5	6	7	8	C2
PARCOM	24.2	15.2	17.7	20.4	20.3	16.4	14.9	12.1	2.0
VSEREC	14.1	6.6	8.8	9.4	10.3	7.8	6.9	6.7	0.1
VSEREG	8.5	6.0	7.2	7.0	8.1	6.9	6.9	7.1	3.4
VESREC	15.6	7.0	8.1	7.6	9.8	7.9	6.8	6.5	0.1
VESREG	9.9	7.0	7.5	8.2	8.5	7.6	7.2	7.2	4.9
GRMREC	12.4	6.3	7.1	7.4	7.4	5.0	3.7	4.2	0.0
GRMREG	6.1	3.8	4.9	5.4	5.6	4.6	3.9	3.7	2.7
IDREC	2.9	1.6	2.2	2.4	2.7	2.2	1.9	1.9	0.4
IDREG	4.7	3.3	3.7	3.6	3.7	3.2	2.6	2.6	1.3
WRDORD	3.7	2.2	2.9	3.5	3.4	2.3	2.1	1.7	0.2
RETENT	14.5	37.8	69.1	114.0	175.1	300.6	415.2	596.4	
LEVEL	3.3	2.3	2.9	3.4	3.6	3.3	2.9	3.4	
HIGH	2.5	2.1	2.0	2.1	1.7	1.5	1.4	1.5	
COLLEG	1.6	0.6	1.2	1.5	1.9	1.9	1.6	2.1	
TAPE	1.4	1.9	2.0	2.5	1.9	1.2	0.1	0.0	
MEAN	3.2	3.1	3.1	3.0	3.1	3.1	3.0	2.7	
GRDREC	3.1	3.0	3.0	2.9	3.0	3.0	2.9	2.8	
TRVLEG	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.4	
TRVLSP	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
FREQEG	0.7	0.2	0.3	0.3	0.4	0.6	0.7	1.0	
FREQSP	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	
DURENG	5.1	2.0	5.4	10.2	8.0	4.6	6.0	7.7	
DURSP	8.3	0.0	7.0	0.0	0.5	0.3	0.0	1.3	
RECENG	4.4	7.1	7.9	16.4	20.4	33.8	36.4	58.6	
RECSP	2.0	0.0	5.2	0.0	3.7	2.0	0.0	2.6	
LSTRAD	103.0	43.4	33.3	10.7	13.5	2.7	3.5	9.2	
LSTTV	77.5	66.7	14.9	10.7	12.0	1.8	5.8	9.6	
LSTFLM	18.2	11.7	7.4	13.4	2.7	1.3	4.3	0.5	
LSTCNV	470.7	91.7	136.5	87.3	11.6	20.5	15.4	6.3	
READNW	390.5	13.4	27.8	15.5	6.8	15.1	5.6	3.1	
READMG	458.6	14.0	30.2	15.7	10.8	16.5	1.9	1.8	
READBK	590.7	14.0	159.1	19.0	40.9	24.2	10.8	2.5	
READCR	429.9	20.8	27.9	70.7	4.6	3.5	15.9	2.4	
SPEAK	380.4	44.0	108.9	56.3	39.1	23.0	15.0	8.8	
WRITE	4.9	1.7	0.9	0.4	1.6	1.2	12.0	0.0	
TOTLST	625.9	223.2	269.2	122.1	39.8	26.3	29.0	25.6	
TOTRED	1,800.6	62.2	244.6	120.9	63.2	59.2	34.2	9.8	
TOTROM	1.0	0.7	1.5	1.5	2.4	2.1	2.4	2.7	2.4
FRENCH	0.5	0.5	1.0	0.6	1.1	0.8	0.9	0.7	
PORT	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	
ITALAN	0.1	0.0	0.1	0.0	0.1	0.2	0.2	0.0	
LATIN	0.3	0.2	1.1	0.8	1.1	1.1	1.3	2.0	

Note. See Table 2 for explanation of abbreviations.

Table 5
Partial Regression Weights and Intercept Values for 8 Groups and 10 Dependent Variables

	Dependent variable									
Predictors	PARCOM	VSEREC	VSEREG	VESREC	VESREG	GRMREC	GRMREG	IDREC	IDREG	WRDORD
INTERCEPT	−7.14	−7.45	1.588	−7.37	1.78	−7.09	−0.22	−1.02	−0.63	−1.81
IND. 1	11.36	6.43	1.19	8.11	2.42	7.26	2.33	0.78	2.08	1.87
IND. 2	4.74	1.01	−0.54	1.58	0.20	2.91	0.78	−0.10	1.08	0.85
IND. 3	5.72	2.09	0.13	1.52	0.26	2.77	1.48	0.26	1.24	1.21
IND. 4	7.44	1.96	−0.27	0.36	0.79	2.52	1.63	0.27	0.97	1.69
IND. 5	6.53	2.33	0.54	2.08	0.81	2.19	1.58	0.51	0.85	1.48
IND. 6	3.37	.48	−0.39	0.78	0.16	0.20	0.84	0.17	0.49	0.46
IND. 7	2.95	.42	−0.20	0.72	0.09	−0.14	0.39	0.02	0.13	0.44
LEVEL	2.16	1.77	0.56	1.79	0.62	1.46	0.57	0.38	0.41	0.37
MEAN	4.05	2.87	1.59	2.79	1.14	2.30	0.60	0.59	0.59	0.74
TOTROM	0.29	0.07	0.16	0.05	0.05	0.01	0.11	0.02	0.07	0.07
TOTRED	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTLST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WRITE	0.02	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
SPEAK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note. See Table 2 for explanation of abbreviations. Ind. = indicator variable.

These products are then added to the intercept value appropriate for that group.

The partial regression coefficients calculated for each of the 10 dependent variables and the intercept values applicable to each group appear in Table 5. In this case the same 14 variables were added to the regression program, in the order listed, for each of the 10 dependent variables. It is apparent that only the variables of level of Spanish training, mean grade received, and the level of training in other Romance languages contribute significantly to the variance accounted for on any dependent variable. This was true regardless of the order in which the variables were entered into the regression program. Adjusted retention functions for all dependent variables based on this procedure are shown in Figures 3 and 4. In calculating these adjusted scores the mean grade in Spanish courses was set at 3, the level of Spanish training was set at 3, and the level of training in other Romance languages was set at 0. These adjusted scores together with the portion of variance accounted for on each dependent variable are presented in Table 6.

In order to render the retention functions for the various dependent variables comparable, Figures 3 and 4 are expressed as a percentage of the original scores for that same variable. The original scores for each variable are the values attained by the student group trained at Level 3 (Table 3, column 3) with minor regression adjustments to reflect a mean grade of 3, and to discount training in other Romance languages. The 10 retention functions exhibit common as well as divergent characteristics. All functions show a rapid loss of information during the first 3 years of the retention interval, followed by a very long period of relatively stable or even improved performance. Thus performance declines as a linear function of the logarithm of time, only for an initial period.

Comparisons among the four functions related to knowledge of individual words show that recognition performance is maintained at a higher level than recall performance, and that the directions of search from English to Spanish and Spanish to English yield nearly identical retention functions for recognition,

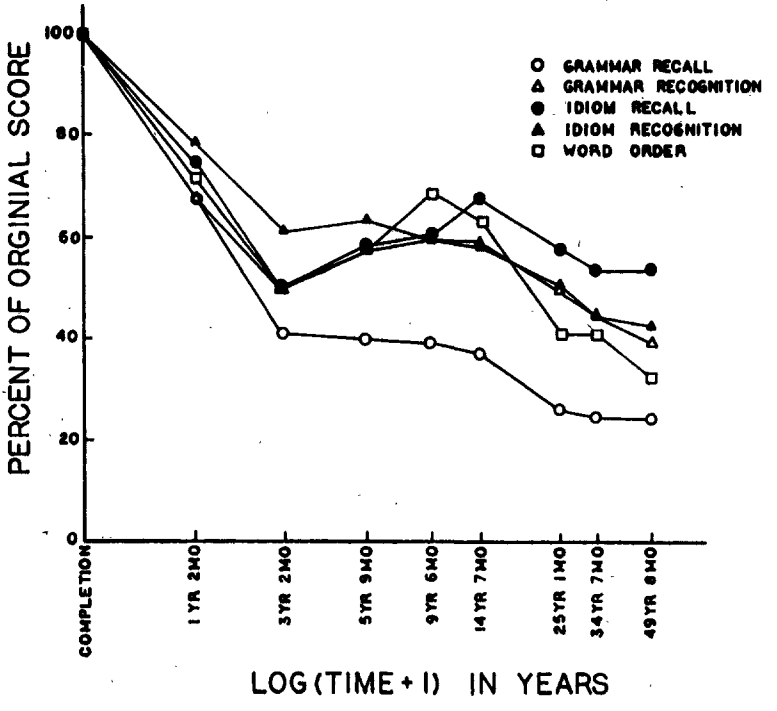

Figure 3. Adjusted retention functions for grammar, idioms, and word order.

but not for recall. The Spanish-to-English recall direction is maintained at a higher level. The superiority of recognition performance to recall must be interpreted in relation to the control baseline provided by the C2 data. These data support the conclusion that performance on subtests for recall reflects almost entirely memory of Spanish training, while performance on recognition subtests reflects, in part, the benefits of guessing, of memory from instruction in other Romance languages, and of information about Spanish acquired incidentally. It is worth noting that such incidental information makes a significant contribution to performance on the subtests for recognition vocabulary, where performance of both C1 and C2 groups significantly exceeds chance success ($p < .01$). In contrast, performance on the idiom recognition subtest falls significantly short of the expected chance level ($p < .01$). The latter result reflects the fact that certain foils on the idiom recognition test are chosen with high frequency because they contain English cognates for portions of the Spanish idiom.

In comparing the recall and recognition functions one must keep in mind that the two types of tests are not based on the same words, and that all retention scores are expressed as a percentage of the performance attained on that same indicant at the end of training.

At the end of 50 years subjects trained at Level 3 perform approximately at Acquisition Level 1 in reading comprehension and recognition vocabulary. However, they perform considerably below that level in recall for Spanish words, in regard to knowledge of proper word order, and particularly in recall for grammar rules. This suggests that reading comprehension is comparatively less affected by a decline of these latter indicants, and is maintained largely on the basis of recognition vocabulary and knowledge of grammar at the recognition level.

An examination of the intercorrelations among all variables yields conclusions in keeping with the results which have been presented. Intercorrelations among all dependent variables and selected independent variables pooled for all retention groups are presented in Table 7. It is apparent that intercorrelations among the dependent variables are quite high and that the dependent variables do not correlate highly with those independent variables

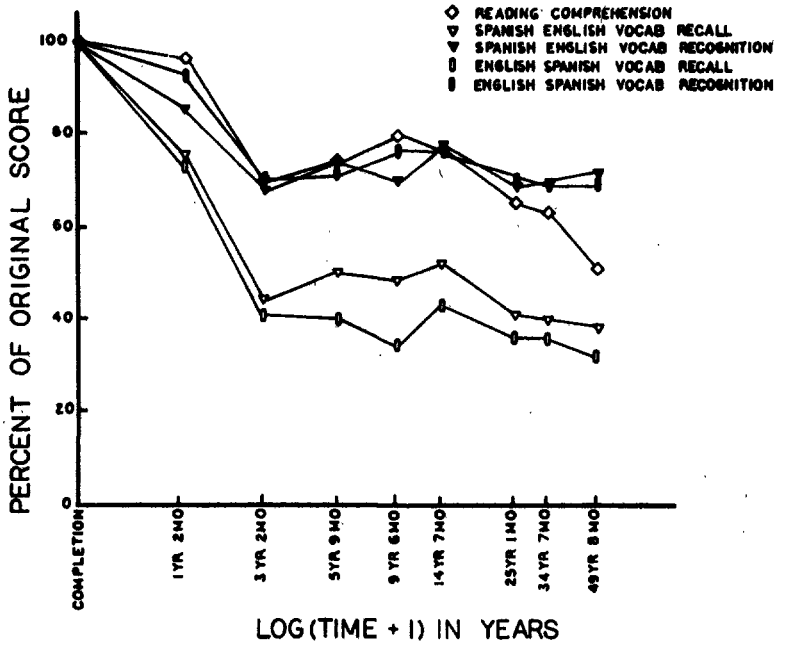

Figure 4. Adjusted retention functions for recall and recognition vocabulary and for reading comprehension.

Table 6
Adjusted Retention Scores for 8 Groups and 10 Dependent Variables

Dependent variable	Time group									
	0	1	2	3	4	5	6	7	8	R^2
PARCOM	25.2	24.16	17.5	18.53	20.25	19.34	16.18	15.76	12.81	42
VSEREC	17.2	12.96	7.54	8.62	8.26	8.86	7.01	6.95	6.53	47
VSEREG	9.3	7.94	6.20	6.87	6.46	7.28	6.35	6.54	6.74	38
VESREC	19.8	14.48	8.17	7.89	6.73	8.45	7.15	7.09	6.37	46
VESREG	10.3	9.48	7.26	7.32	7.85	7.87	7.22	7.15	7.06	40
GRMREC	17.2	11.45	7.10	6.96	6.71	6.38	4.39	4.05	4.19	50
GRMREG	8.4	5.63	4.08	4.78	4.93	4.88	4.14	3.69	3.30	38
IDREC	3.6	2.67	1.80	2.09	2.16	2.40	2.06	1.91	1.89	39
IDREG	5.8	4.52	3.51	3.68	3.41	3.29	2.93	2.57	2.44	36
WRDORD	4.8	3.39	2.36	2.73	3.22	3.00	1.98	1.95	1.52	33

Note. See Table 2 for explanation of abbreviations.

reflecting rehearsal during the retention interval. The dependent variables do correlate with independent variables defining original training, for example, the level of Spanish training, the mean grade received in Spanish courses, and the level of training in other Romance languages. The low correlation between retention of Spanish and rehearsal variables such as reading, listening to, or speaking Spanish during the retention interval, reflects the fact that scores on these rehearsal variables are extremely low for the great majority of subjects. Thus it is not appropriate to conclude from our data that practice does not help in the retention of knowledge. Rather, we find that our subjects rehearse their knowledge minimally or not at all, and that the data therefore reflect no important influence of the rehearsal variables. Those subjects who rehearse tend to do so only during the first year of the retention interval (see Table 4). After that time the mean number of minutes spent in reading Spanish ranges from 10 min to 240 min per year for the various groups. The mean number of minutes of listening to Spanish ranges from 25 min to 253 min per year, and for speaking Spanish, from 9 min to 70 min per year. There is good reason to believe that even these low numbers are overestimates caused by the nature of our questionnaire, which emphasized rehearsal, and by the nature of our calculation, which assumed that the midpoint values of rehearsal frequency categories best represented the data in these categories. The absence of rehearsal effects must also be interpreted in relation to the amount of knowledge to be rehearsed. The probability of reexposure to individual words or items on our test is quite small when subjects rehearse 1 or 2 hours per year to cover a vocabulary of several thousand words. It is therefore not surprising that the correlations of indicated rehearsals with the dependent variables are negligible. For these reasons the regression equations for predicting retention do not include variables related to the amount or type of practice during the retention interval. The fact that most of our subjects failed to rehearse was at first a most disappointing finding because it precludes attaining one of the objectives of this investigation, that is, to estimate the type and amount of rehearsal needed to maintain various levels of language performance. It will be shown in the General In-

Table 7
Intercorrelations Among Dependent and Selected Independent Variables

Independent and dependent variables	Dependent variable									
	PARCOM	VSEREC	VSEREG	VESREC	VESREG	GRMREC	GRMREG	IDREC	IDREG	WRDORD
PARCOM	1.00	0.79	0.71	0.76	0.76	0.74	0.59	0.72	0.67	0.70
VSEREC	0.79	1.00	0.77	0.88	0.79	0.80	0.68	0.79	0.74	0.68
VSEREG	0.71	0.77	1.00	0.73	0.74	0.67	0.60	0.70	0.64	0.59
VESREC	0.76	0.88	0.73	1.00	0.77	0.82	0.68	0.75	0.72	0.68
VESREG	0.76	0.79	0.74	0.77	1.00	0.74	0.58	0.71	0.65	0.65
GRMREC	0.74	0.80	0.67	0.82	0.74	1.00	0.72	0.72	0.71	0.69
GRMREG	0.59	0.68	0.60	0.68	0.58	0.72	1.00	0.64	0.60	0.59
IDREC	0.72	0.79	0.70	0.75	0.71	0.72	0.64	1.00	0.66	0.63
IDREG	0.67	0.74	0.64	0.72	0.65	0.71	0.60	0.66	1.00	0.62
WRDORD	0.70	0.68	0.59	0.68	0.65	0.69	0.59	0.63	0.62	1.00
LEVEL	0.50	0.55	0.51	0.51	0.50	0.51	0.53	0.54	0.48	0.44
MEAN	0.41	0.42	0.39	0.39	0.39	0.41	0.31	0.38	0.34	0.36
SPEAK	0.12	0.18	0.12	0.17	0.13	0.20	0.16	0.17	0.14	0.14
WRITE	0.11	0.15	0.16	0.10	0.13	0.09	0.14	0.15	0.14	0.10
TOTLST	0.12	0.17	0.14	0.18	0.13	0.22	0.18	0.18	0.15	0.15
TOTRED	0.08	0.14	0.13	0.14	0.11	0.14	0.17	0.14	0.14	0.08

Note. See Table 2 for explanation of abbreviations.

Table 8
Partial Regression Weights With Time as an Independent Variable, and Higher Order Terms Included in the Regression Program

	Dependent variable									
Predictors	PARCOM	VSEREC	VSEREG	VESREC	VESREG	GRMREC	GRMREG	IDREC	IDREG	WRDORD
INTERCEPT	12.65	6.30	6.84	11.46	6.84	10.46	7.40	2.49	3.40	2.70
LOG RET	−0.17	0.94	−1.51	−7.98	0.22	−9.40	−4.64	−0.96	−1.77	−3.02
(LOG RET)^2	−6.88	−6.09	−0.39	−2.24	−2.76	2.96	2.42	−0.23	0.47	1.63
(LOG RET)^3	3.78	2.96	0.45	2.23	1.40	−0.30	−0.44	0.31	0.00	−0.30
(LOG RET)^4	−0.58	−0.41	−0.08	−0.35	−0.20	−0.02	0.01	−0.06	−0.01	0.01
LEVEL	4.50	3.88	1.14	3.03	1.31	2.08	0.92	0.61	0.71	0.66
(LEVEL)^2	−0.18	−0.14	−0.04	−0.10	−0.05	−0.06	−0.02	−0.02	−0.02	−0.02
MEAN GRADE	−5.30	−5.86	−2.18	−3.33	−1.61	−3.04	−2.74	−1.52	−1.16	−0.87
(MEAN GRADE)^2	1.64	1.55	0.58	1.10	0.47	0.98	0.62	0.38	0.31	0.29
TOTROM	0.36	0.15	0.18	0.17	0.09	0.11	0.14	0.05	0.08	0.09
R^2	0.47	0.53	0.43	0.58	0.47	0.58	0.46	0.44	0.44	0.38

Note. See Table 2 for explanation of abbreviations. LOG RET = Natural log of retention interval (in years) plus one.

terpretation and Discussion section, however, that this finding is basic to the major theoretical conclusion of this investigation, and thus it turns out to be most fortuitous.

Two considerations led to the decision to apply a second, somewhat different method of analysis to the retention data. (a) Scattergrams constructed for individual correlations of the level of training variables and retention variables showed strong indications of nonlinear regression, and (b) the possibility of systematic differences among the subject populations sampled in various time groups made it desirable to minimize such effects by a method that is not based on the assignment of subjects to groups and that permits some smoothing. The revised analysis corrected for these problems by (a) entering higher order terms for all independent variables in the regression analysis, and maintaining these terms in the regression equation if their inclusion led to significant increases in the predictable portion of the variance of any of the dependent variables; and (b) treating retention time as an independent quantitative variable, rather than as an indicator variable. Thus, instead of adjusting mean retention performance of each group upward or downward to correct for inequalities among the groups in regard to independent variables, the assignment of subjects to groups was disregarded, and the retention interval pertaining to each subject was expressed as log (1 + retention interval) and entered as an additional independent variable in the analysis. The partial regression weights resulting from this analysis are shown in Table 8 for each of the 10 dependent variables together with the portion of the variance accounted for. It can be seen that the same independent variables are represented in this analysis as in the analysis based on cross-sectional adjustment of group means, but higher order terms are included for the variables of retention time, level of Spanish training, and mean grade. Comparing column 10 in Table 6 with row 11 of Table 8 shows that this method of analysis yields a higher portion of variance accounted for in the case of every dependent variable. The increments range from 5% to 12% and average 7%. What may be termed contour retention curves for each of the 10 dependent variables, based upon the regression weights in Table 8, appear in Figures 5–10. To obtain the functions shown in Figures

5–10, the regression equation for each dependent variable was evaluated for successive retention intervals corresponding to the mean intervals of each of the 8 time groups. These intervals were chosen in order to obtain comparable reference points; the equations can, of course, be evaluated for any retention interval. At each retention interval the equations were evaluated for three levels of Spanish training (1, 3, and 5), and in Figure 10, for two mean grade levels (A and C). The graphs in Figures 5–9 show three retention curves reflecting the effect of level of training, with the mean grade fixed at C, and the graphs in Figure 10 show two retention curves reflecting the effect of the mean grade, with the level of training fixed at 3. The level of training in non-Spanish Romance languages was set at 1.41, the mean value for all subjects. Retention performance is expressed as a predicted raw score for each variable, rather than as a percentage of the original score. This makes it possible to illustrate the effects of level of training and mean grade. Inspection of Figures 5–10 supports most of the previous conclusions reached on the basis of the linear, group adjustments, but there are significant additional findings. The reading comprehension function again shows losses for the first 3 years of the retention interval, followed by a 20-year period of relative stability. Pronounced losses occur again between 35 and 50 years after training. The effects of level of training and of the mean grade are quite strong, and because

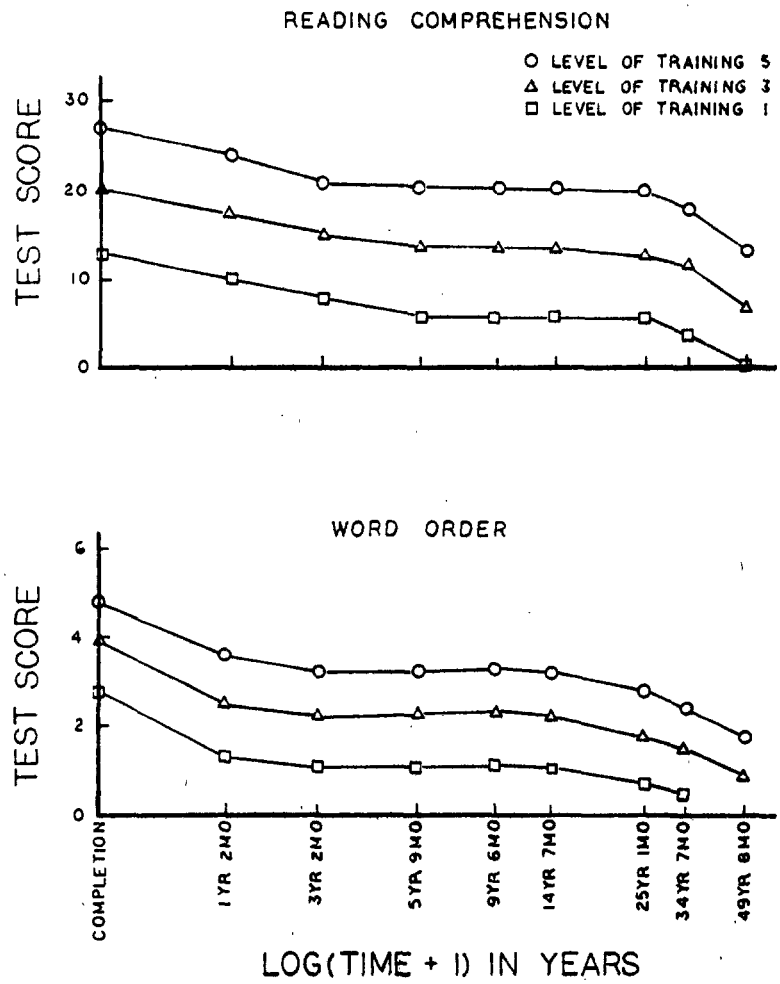

Figure 5. The effects of level of training on the retention of reading comprehension and word order.

the absolute amount of these effects remains the same throughout the retention interval in accordance with homogeneity of regression, the effects become relatively more important as time passes. There is some evidence that the correlations of dependent variables with levels of training and mean grade diminish somewhat toward the end of the retention interval. Because this diminution was not statistically significant, homogeneity of regression was assumed and the predicted retention curves for various levels of training and for various grades do not converge. If this diminution of correlation were reflected in Figures 5–10, the contour functions would converge somewhat during the last 15 years and this would also correct for the anomaly of projected negative scores at the end of the retention interval.

Comparison of retention for recall versus recognition subtests must again take into account the baseline performance reflected by the C2 data. Recognition vocabulary for students trained at Level 1 who earn a grade of C declines approximately to the baseline level 3–6 years after training. This is quite comparable for most subtests including those for recall vocabulary, where the baseline is close to zero. Recall vocabulary stabilizes somewhat later, and the level of stabilization is relatively

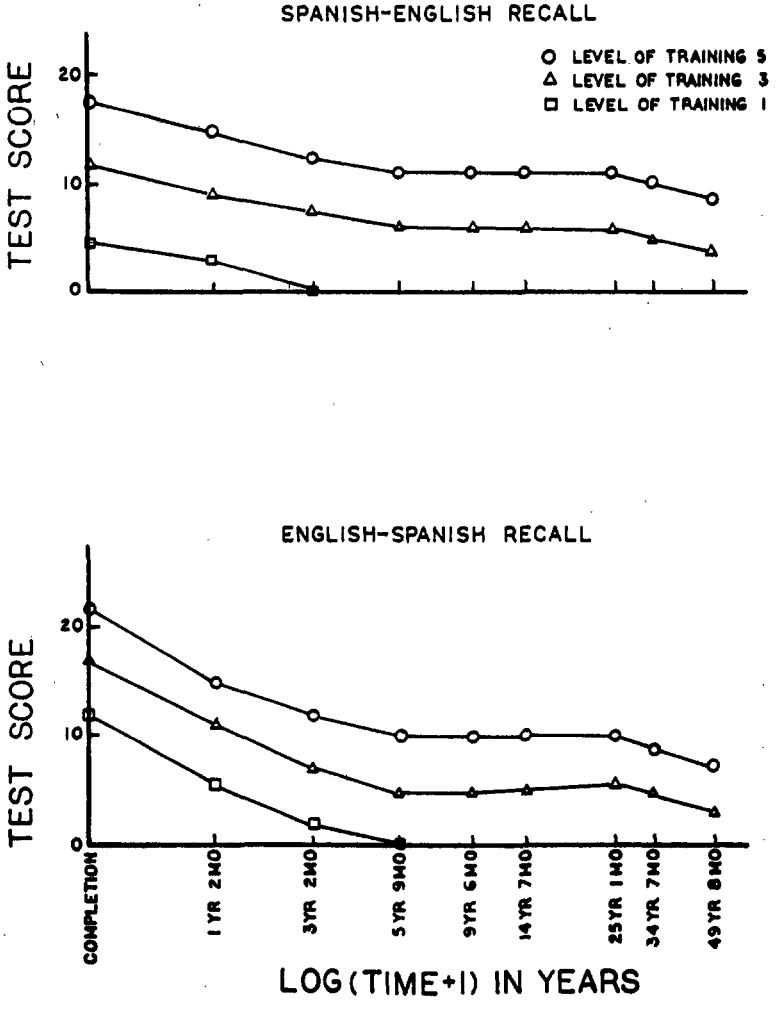

Figure 6. The effect of level of training on the retention of recall vocabulary.

higher for recalling the English equivalents of Spanish words than for retrieval in the reverse direction. Individuals who receive grades higher than C, or who are trained beyond Level 1, maintain permanent knowledge above the respective baselines in all subtest areas.

The recall for grammar declines most precipitously and is one of the two subscores which shows no clear evidence of stabilizing during the retention interval. At the end of 50 years C students have lost virtually all of the grammar information they once had at the recall level, and the scores of A students decline within 1 year to the original level of performance of C students. Recognition for grammar fares relatively better. Performance stabilizes 3 years after training, and those trained at Level 5 retain substantial knowledge for about 20 years before showing a further pronounced decline. The function for the recall for English equivalents of Spanish idioms closely parallels the function for the recall for individual Spanish words, and the effects of earned grade are also quite comparable for these functions. The recognition for Spanish idioms shows more pronounced and continuous decline than the recognition for individual Spanish words. There is no clear period of stability, and it is perplexing that the relative losses are more severe than for the recall for idioms, particularly during the later portion of the retention interval. It is possible that the

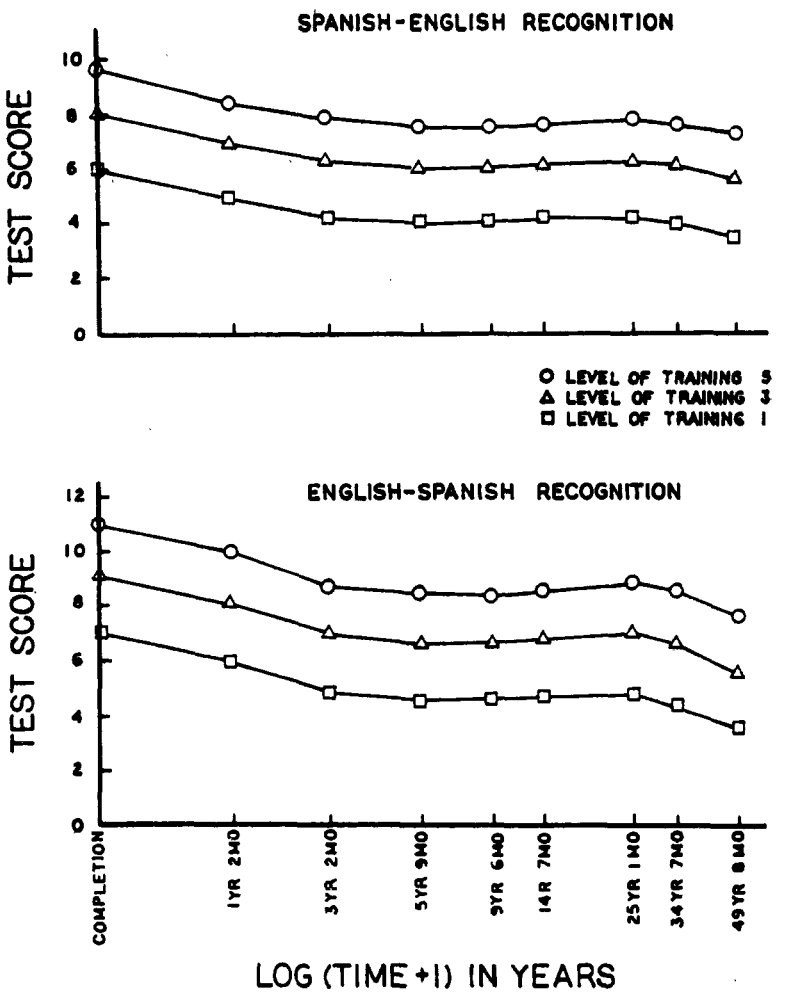

Figure 7. The effect of level of training on the retention of recognition vocabulary.

use of cognate foils on this subtest is responsible not only for performance below the chance level for control subjects but also for a continuous decline of the performance of other subjects during the retention interval. Knowledge of word order stabilizes for a period of at least 20 years after the initial losses, but ultimately there are additional losses which leave C students with very little of the original knowledge at the end of 50 years.

Methodological Caveats

A variety of problems may affect the validity of cross-sectional research. These problems have been discussed by Lachman, Lachman, and Taylor (1981), Schaie (1977), Bahrick and Karis (1982), and others. We have already presented data to reveal the magnitude of errors affecting scores based on subjects' long-term memory reports. In addition, there may be variables confounded with the retention interval which may affect the data but remain unassessable. Thus the methods of teaching Spanish may change, so that Training Level 3 may not reflect the same amount of knowledge now as it did 50 years ago; grade inflation may occur so that an A does not stand for the same amount of knowledge as it did 50 years ago, and the talent of students selecting Spanish courses may change so that individuals belonging to various time groups may represent different populations.

The bottom line for evaluating the validity of the use of the adjustment method in a par-

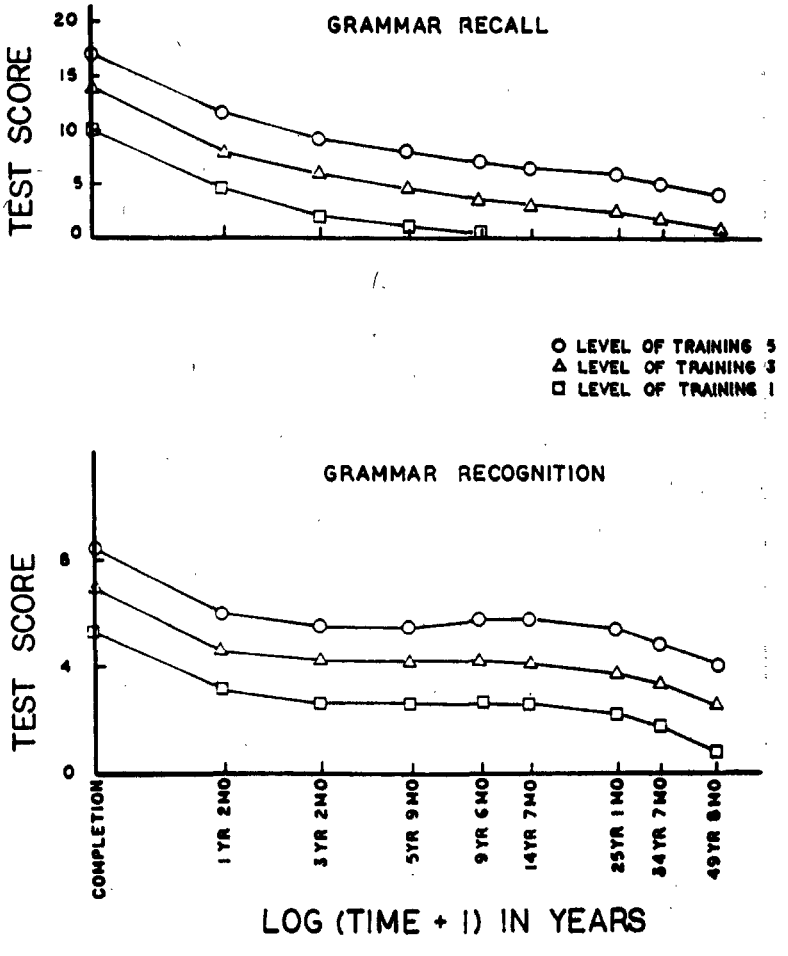

Figure 8. The effect of level of training on the retention for grammar.

ticular cross-sectional investigation is the multiple correlation yielded by the regression equations which predict dependent variables from independent variables. The multiple correlations obtained in this investigation range from .61 to .77 for the 10 dependent variables, with a median correlation of .69. These correlations are based on a very large sample, and are therefore subject to only small statistical errors. The multiple correlations establish validity, and therefore also the reliability of the data, taking into account the aggregate effects of all error sources that have been mentioned. In other words, the multiple correlations between independent variables and retention performance indicate how well the amount of knowledge retained at any point in time can be predicted on the basis of the subject's report of level of training, time of training, and grade received, in spite of changes in grading standards, errors in reporting, and changes of talent among those who selected Spanish courses. For most of our dependent variables, the regression analysis accounts for approximately 50% of variance, a proportion which must be considered high in light of the complexity of the phenomena investigated and the variety of error sources that have been discussed. The

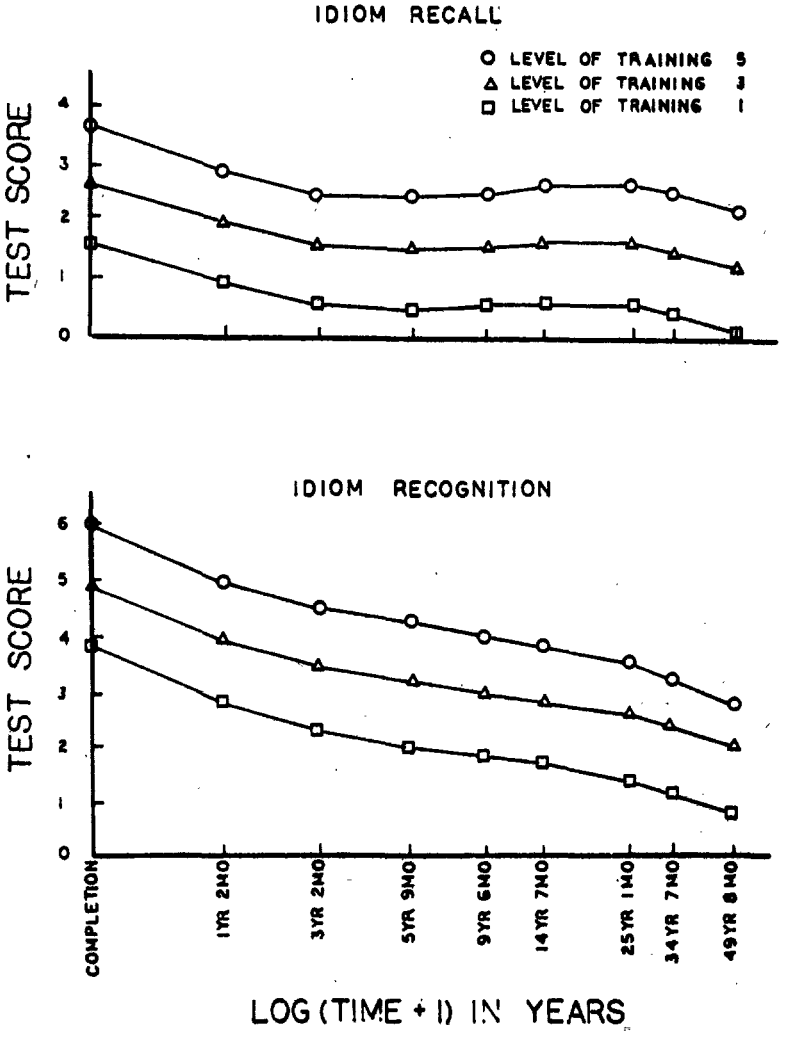

Figure 9. The effect of level of training on the retention for idioms.

acceptability of findings in laboratory investigations is not usually evaluated in terms of the proportion of variance of dependent variables accounted for by independent variables, although such evaluations would have substantial merit. Rather, the minimum standard of acceptability is met if the independent variables produce statistically significant effects on the dependent variables, regardless of the proportion of variance they account for. This latter test is obviously met for the major effects examined in this investigation, but it is not an appropriate way of evaluating validity here. Continued experience with large-scale investigations of naturalistic memory will help to establish standards and further improve methodology in this area, so that these methods can be used more extensively in memory research.

General Interpretation and Discussion

When retention curves represent the number, or the percentage, of correct responses on the ordinate, the slope of the retention function can easily be related to the frequency distribution of the life span of responses. A retention function of constant slope indicates that a constant number of responses are lost per unit of time, and this implies a flat frequency distribution for the life span of responses, that is, a distribution in which an equal number of responses fall into each life-span interval. An exponentially declining retention function

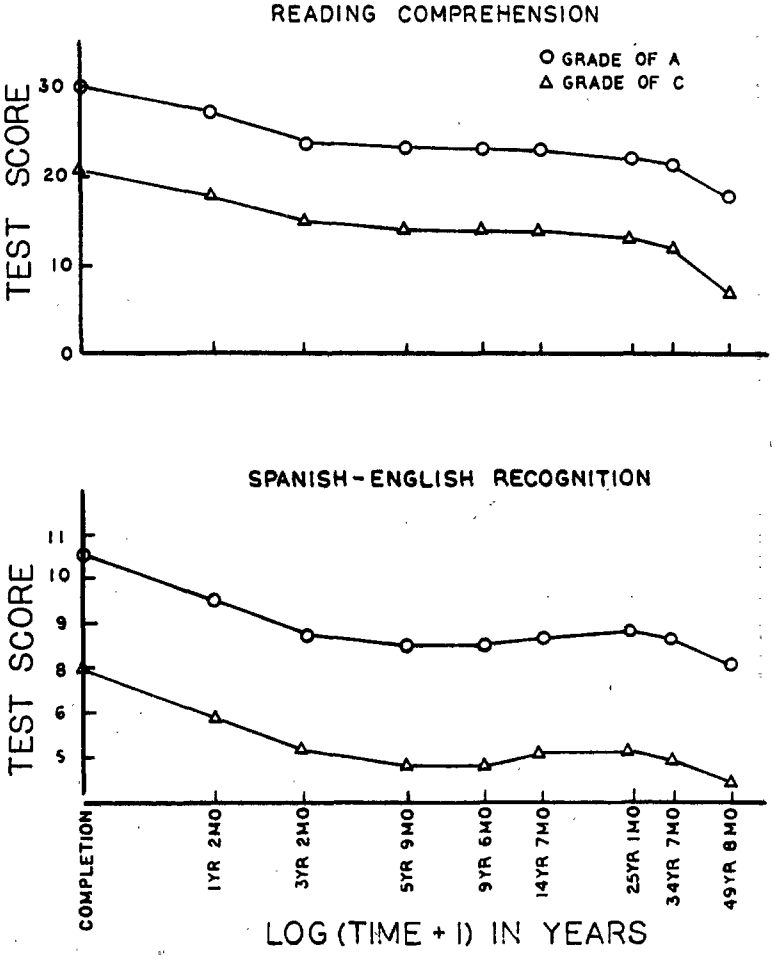

Figure 10. The effect of earned grade on the retention for reading comprehension and recognition vocabulary.

indicates that a diminishing number of responses are lost in successive, equal intervals of time. This requires a frequency distribution for the life span of responses which is skewed in the direction of a longer life span, that is, the highest frequency corresponds to responses with short life spans, and diminishing frequencies are associated with responses of longer life spans. A related analysis has been discussed in an earlier paper (Bahrick, 1965) and the preceding examples are illustrated in Figure 11, which shows the frequency distributions corresponding to a straight line and an exponentially declining retention function. It is, of course, the exponential retention function and its corresponding frequency distribution that have typically been obtained in episodic memory research conducted in the laboratory. However, memory research usually terminates before all of the tested information is lost, and in that case there is no way of knowing what eventually happens to the remaining information. Gradual losses may continue indefinitely, or they may end as the retention curve approaches an asymptote above the base line of zero knowledge.

The Concept of a Permastore

The retention functions obtained in this investigation are not of the type illustrated in Figure 11. Rather, 8 of the 10 functions shown in Figures 5–10 fall exponentially for a period of 3 to 6 years. They then remain flat for several

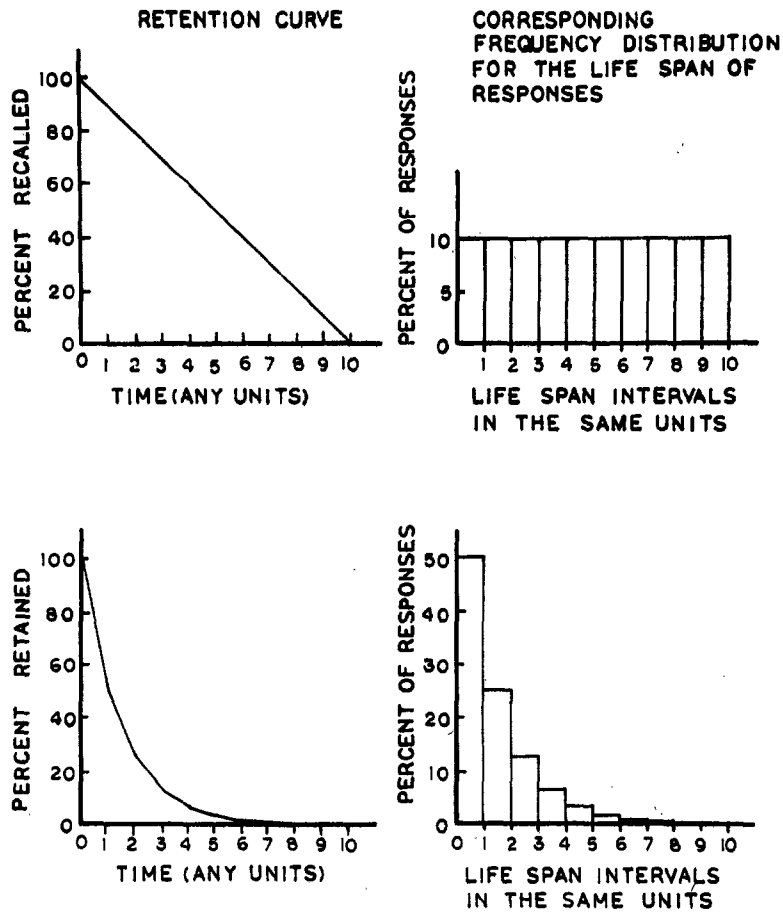

Figure 11. Frequency distributions for the life span of responses corresponding to straight-line and logarithmic retention functions.

decades, after which they show an additional positively accelerated decline. Based on a response life-span analysis these retention functions correspond to a frequency distribution of responses that is discontinuous. One portion of the distribution has life spans of 0 to 6 years, with relative frequencies distributed similarly as has been found in episodic memory research, except for the fact that the mean life span is much longer here. The other portion I will call the "permastore." This memory content has a distribution of life spans of 25 years or longer, and the distribution is skewed in the direction of shorter life spans. The largest number of these responses survives 50 years or longer, and diminishing numbers are lost during the two preceding decades. The two portions of the distribution are discontinuous, that is, there is a period from approximately 5 to 25 years after training during which no

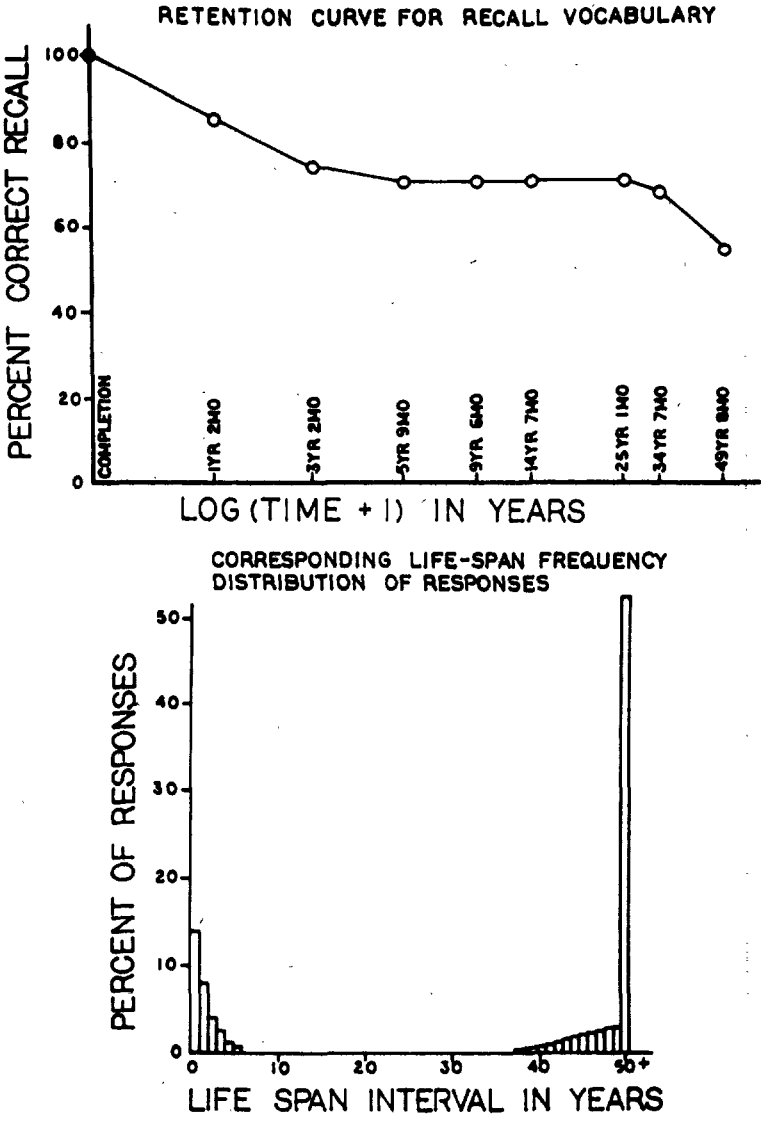

Figure 12. Frequency distribution for the life span of responses corresponding to the retention of Spanish–English recall vocabulary.

responses appear to be lost, and the frequency of responses with life spans within these limits is therefore near zero. Figure 12 shows a life-span frequency distribution typical for the data which have been reported here.

The portion of the distribution in permastore varies with the level of training, the mean grade achieved, and the nature of the required response. Individuals trained at Level 1 who earned a grade of C retain very little of their original knowledge in permastore. Those trained at higher levels and those who earned higher grades retain increasing portions: Individuals with a mean grade of A retain approximately 52%, 72%, and 80% of Spanish–English recall vocabulary for Training Levels 1, 3, and 5 respectively; individuals with a mean grade of C retain only 0%, 53%, and 73% at the three training levels.

This life-span analysis applies directly only to those dependent variables for which individual responses are reasonably independent of each other. The analysis therefore applies to recall and recognition vocabulary, but not to the scores for reading comprehension. Correct answers to questions regarding the meaning of a sentence or a paragraph depend not only on knowledge of vocabulary but also on knowledge of grammar, word order, and so forth, and success or failure in answering the questions can therefore not be directly related to the life span of a response. It will be noted, however, that the memory functions obtained for reading comprehension do closely parallel the memory functions for recognition vocabulary, and that the correlation between reading comprehension scores and the various analytical scores is high. It would therefore appear that the decline and maintenance of reading comprehension can be adequately predicted on the basis of the analysis of the life-span frequency distribution of individual responses, and the concept of permastore remains applicable, although the analysis into a life-span frequency distribution is not directly applicable.

It does not really come as a surprise that semantic memory contains much semipermanent information. Everyone knows that we rarely forget the meaning of most words in our native language, the rules of arithmetic, and many other facts about the world. However, psychological research has not dealt directly with the process by which knowledge becomes permanent, so that the necessary conditions for this transition are not well understood. It is not clear, for example, to what extent the maintenance of knowledge in permastore depends on periodic access or rehearsal. If retention measurement stops several days, weeks, or years after original training, the fate of any remaining knowledge is conjectural. The most noteworthy finding of this investigation is almost certainly the fact that a very large amount of information is maintained in permastore under conditions of minimal rehearsal. This conclusion is possible because of the fortuitous circumstance that the great majority of individuals who were subjects in this investigation rehearsed very little or not at all, and that their retained knowledge bears no significant relation to the small amount of reported rehearsal. Our results show that very significant portions of semantic knowledge remain perfectly accessible for decades without being used at all.

We are now able to reconcile the strikingly divergent results obtained in two earlier investigations of long-term memory for names and faces. Data obtained from Bahrick et al. (1975) and from Bahrick (in press) are combined in Figure 13. The earlier study shows that the names and faces of high school classmates are recognized at about the same level of accuracy 25 years after original exposure as they are immediately after graduation, even when the estimated effects of rehearsals are statistically removed. In contrast, the later study shows that the accuracy of recognizing the names and faces of former students by their college instructors declines with the logarithm of time. The decline begins very soon after exposure, and relatively little information survives beyond 8 years. Memory for the names and faces of high school classmates is based on a 4-year period of interaction during which most of the information necessary for recognition has apparently attained permastore status. In contrast, memory for the names and faces of former students was based on 10 weeks of much more restricted interaction in the classroom. It appears that comparatively little of that information has become permanent. These findings indicate that dichotomous durability distributions may characterize a variety of semantic memory content.

There are various sources of evidence to suggest that the concept of permastore may not be limited to semantic memory content. Brown and Kulik (1977) reported long enduring memory for salient episodic experiences called "flashbulb" memories, and reports by Penfield and Perot (1963) based on findings obtained through brain stimulation indicate that certain images may be preserved for long periods with great clarity. Neisser (1967) cites motor skills, for example, bicycle riding or piano playing, and well-rehearsed verbal performances by old actors, as illustrations of other memories which endure without the benefit of intervening rehearsals.

It is important to point out that the term permastore has been used here without any intended structural implications. It simply refers to the finding that much of the information in memory has a life span of several decades, apparently without requiring periodic access or relearning.

Implications for the Acquisition Process

Significant questions regarding the maintenance of information in permastore concern the relative importance of the acquisition process versus the effect of conditions prevailing during the retention interval. Variance of the life span of responses might result from conditions present during the period of acquisition, from conditions present during the retention interval, or from some combination of both. It has already been shown that rehearsal during the retention interval played no important role in maintaining knowledge of Spanish. The data support the further inference that variation of conditions of interference encountered during the retention interval did not play a major role in determining the portion of information retained in permastore. It is difficult to conceive of conditions of interference that would yield the discontinuous life-span frequency distribution characteristic

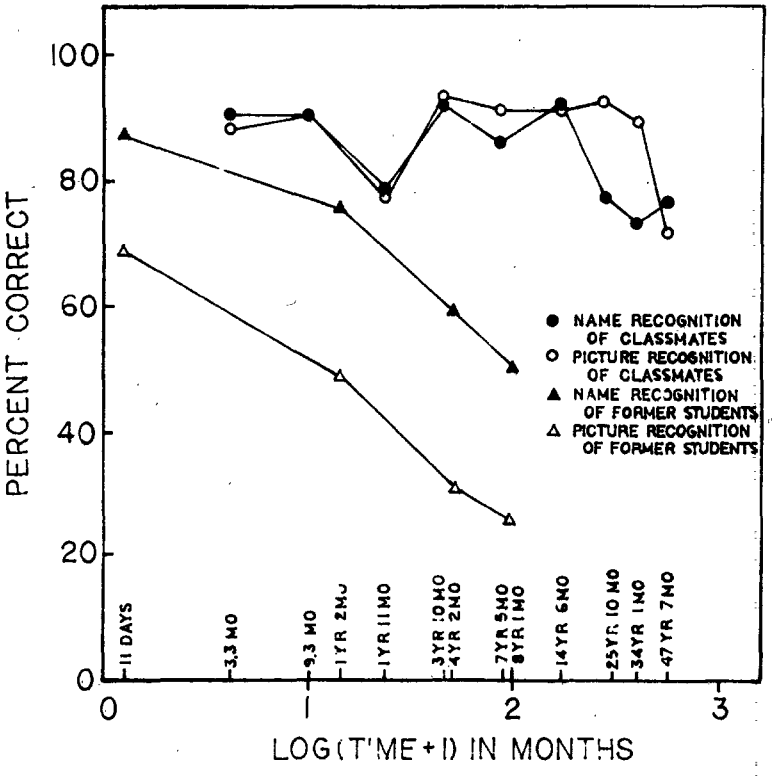

Figure 13. Comparison of retention of former classmates and former students, based on data from Bahrick et al. (1975) and Bahrick (in press).

of much of the present data. The amount of interference affecting various portions of a large recognition vocabulary is likely to follow a normal or at least a continuous distribution.

The sharp contrast between recognition for names and faces of high school classmates versus the recognition for names and faces of former students is also best explained on the basis of differences in the degree of original learning, rather than differences in the degree of interference sustained during the retention interval. At the end of original exposure, name recognition is slightly below 90% correct in both investigations. This level is maintained for at least 25 years in the study of high school classmates, but the level has fallen to about 50% within 8 years in the study of memory for the names of former students. This is equally true for instructors who retire soon after teaching their classes, and for younger instructors who continue to teach and are subject to the additional interference associated with learning names and faces of new students. Thus the interference due to learning new names and faces does not affect recognition of the names and faces of former classmates for at least 25 years, but comparable interference is associated with continued decline in recognizing names and faces of former students because this information never attained permastore status. All of these considerations support the conclusion that discontinuity of the life-span frequency distribution is determined during the acquisition period, and is relatively unaffected by normal interference encountered during the retention interval.

Semantic memory content is typically acquired over extended time periods during which exposure or active rehearsal is limited to relatively short periods spaced at intervals. This is true of knowledge acquired in formal learning sessions, for example, foreign-language classes, but it also applies to the casual learning of names and faces of people we meet repeatedly. Practice sessions may be more or less clearly defined, but in most instances intervals intercede between sessions, and without repeated exposure only a small portion of the information acquired during the first exposure would endure (Bahrick, 1979). Acquisition is the cumulative result of successive relearning sessions, with a portion of the material forgotten during the intervals between sessions. Melton (1963) showed that this same process operates in traditional laboratory learning of episodic content, during the alternation of trials and intertrial intervals, but in that case the whole process is compressed into a short time span, whereas the acquisition of semantic knowledge may continue over a period of several months or years. It has long been known that the distribution of practice sessions is an important variable determining the durability of acquired knowledge, and the results of this investigation suggest that extension of the reexposure to information over long time periods produces a cumulative effect which eventually gives permanence to responses and renders them invulnerable to most interference effects.

It would appear that the transition to this state of permanence occurs during acquisition and is discrete, rather than continuous, even though the transition reflects the cumulative effect of successive relearning sessions. If successive reexposure would gradually increase the life span of responses, we would expect a continuous frequency distribution of the life span with many responses of an intermediate longevity. The obtained distribution indicates such an effect only for the portion of the distribution with life spans of less than 6 years. The life span of the remaining responses does not appear to have been extended gradually. Had this been the case one would expect many responses to show intermediate life spans of 10, 15, or 20 years. The fact that there are no responses with these intermediate life spans indicates a discrete transition during acquisition from long-term storage to permastore. This interpretation differs from the position taken by Rock (1957) regarding the discrete acquisition of paired-associate responses, in that the discrete process is assumed here only for the transition to permastore status, not for increments in the life span of responses up to approximately 6 years.

The thrust of this research is directed at the large amount of information that constitutes permanent knowledge of the individual. Neither the conditions of acquisition of permanent knowledge, nor the conditions of its maintenance have been the direct object of psychological research. It is apparent that although a portion of the information in long-term memory remains there only if it is periodically

used or rehearsed, another very significant portion attains permastore status during acquisition and requires no further access or rehearsal during the life span of the individual. Research directed at the first portion must concentrate on conditions of maintenance; research directed at the second portion must concentrate on conditions of acquisition. It is clear that both types of research are essential for the development of a more integrative conceptualization of memory, and for the development of educational programs based on sound psychological knowledge.

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Appendix A

Portions of Each Subtest of Spanish

Reading Comprehension

Directions: Read the following selections and answer the question in the space provided. Answer in English.

La política en la casa (Modern Language Association, 1973)

Ramón: Pues digan lo que digan Vargas Campo es el hombre del diá.
Padre: No digas tonterías. Es un loco idealista que todo lo quiere cambiar. ¡Nuestro pueblo jamás lo va a aceptar!
Ramón: A pesar de lo que tú digas, papá, no estoy de acuerdo contigo.
Madre: Les ruego que no discutan más de política. Cambiemos de tema.
Ramón: ¿De qué quieres que hablemos, mamá? ¿De vestidos?
Madre: Es que ustedes dos nunca se ponen de acuerdo. Siempre terminan en un pleito.
Padre: Dejemos ese tema. De todos modos, quería hablarte de otra cosa más importante, tus estudios.
Ramón: Por favor, no insistan en que estudie medicina.
Padre: No nos vamos a oponer a lo que tú escojas. Tú eres el que decides. Pero . . .
Madre: Lo único que te pedimos es que no estudies para abogado.
Ramón: ¿Qué hay de malo en eso?
Madre: Es que hay tantas abogados que es muy difícil destacarse en ese campo.
Padre: A menos que uno se meta en la política y ojalá que tu no te dediques a eso. Que lo hagan otros.
Madre: Bueno, sigan ustedes hablando de eso. Voy a ver como anda lo de la comida.
Ramón: . . . Mira, papa, Volviendo a lo otro.

1. Why doesn't Father like Vargas Campo?
2. Why doesn't Mother want the family to talk politics?
3. What topic does Father want to discuss?
4. Why doesn't Mother want Ramon to be a lawyer?
5. What did Mother have to do?

Vocabulary: Spanish to English Recall

Directions: Write the English meaning of the Spanish word in the appropriate place on this page.

	Answer
1. llamar	1. _____
2. ojo	2. _____
3. razon	3. _____

Vocabulary: Spanish to English Recognition

Directions: Write the number of the correct English meaning of the Spanish word in the answer column.

1. _____ feliz
   1) happy 2) fault 3) feet 4) new 5) clean
2. _____ mandar
   1) to make 2) to mend 3) to yell 4) to command 5) to arrange
3. _____ romper
   1) to roam 2) to break 3) to look 4) to roar 5) to search

Vocabulary: English to Spanish Recall

Directions: Write the Spanish meaning of the English word in the appropriate place on this page.

	Answer
1. time	1. _____
2. to hear	2. _____
3. to read	3. _____

Vocabulary: English to Spanish Recognition

Directions: Write the number of the correct Spanish meaning of the English word in the answer column.

1. _____ to reach
   1) sentar 2) cambiar 3) recoger 4) alcanzar 5) cumplir
2. _____ lady
   1) dama 2) hermano 3) semana 4) marques 5) sistema
3. _____ date
   1) mesa 2) fecha 3) cuenta 4) niña 5) fina

(Appendix continued)

Grammar Recall

Directions: Write the correct form of the verb given in the blank provided.

1. El _____ español. (estudiar)
   He studies Spanish.
2. Yo _____ la menor. (ser)
   I am the youngest.
3. Ellos _____ ir conmigo. (poder)
   They are able to go with me.

Grammar Recognition

Directions: Write the *number* of the correct form of the verb in the answer column.

1. _____ They are going there for the holidays.
   Ellos _____ allí para los dias feriados.
   1) vayan 2) iban 3) van 4) fueron 5) va
2. _____ Enter the room.
   _____ ustedes al cuarto.
   1) pasen 2) pasan 3) passaron 4) passarían 5) pasaban
3. _____ Yesterday they gave me 10 pesos.
   Ayer me _____ diez pesos.
   1) dan 2) den 3) dieron 4) daron 5) daban

Idiom Recall

Directions: Write the correct English meaning of the Spanish idiom in the answer column.

Idiom	Answer
1. hace mal tiempo	1. _____
2. hasta la vista	2. _____
3. en vez de	3. _____

Idiom Recognition

Directions: Choose the correct English meaning of the Spanish idiom and write the number in the answer column.

1. _____ sin embargo
   1) without restriction 2) almost 3) an embargo 4) nevertheless 5) sometimes
2. _____ tal vez
   1) perhaps 2) many times 3) certain times 4) all the time 5) once upon a time
3. _____ desde luego
   1) from then on 2) as soon as 3) later than 4) of course 5) at a later time

Word Order

Directions: The Spanish words are not in the correct sequence. Put the Spanish words into the correct order *on this page* by using the numbers associated with the words. For example, a possible answer for the first question might be 12534678.

1. Henry did not explain to me clearly all the problems.
   Enrique no explicó me claramente todos los problemas.
   1 2 3 4 5 6 7 8
   Answer: _____
2. When the letter arrived, Carlos had left.
   Cuando la carta llegó Carlos había partido.
   1 2 3 4 5 6 7
   Answer: _____
3. Helen did not like the play.
   Elena a no (le) gustó la comedia.
   1 2 3 4 5 6 7
   Answer: _____

Appendix B

Summary of the Questionnaire

Language Training

Subjects provided information concerning the number of years of Spanish taken in high school and the number and level of Spanish courses taken in college. They indicated the letter grades received in each course, the dates of completion of each course, and the name and location of the school where the work was taken. They identified courses in which frequent use was made of a listening laboratory. Similar information was obtained for courses taken in Latin, French, Italian, and Portuguese, and subjects were asked to indicate any other learning opportunities for Romance languages, such as residence abroad, or residence in a bilingual area.

Rehearsal Opportunities During the Retention Interval

Rehearsal opportunities were grouped into the categories of exposure through listening, reading,

(Appendix continued)

speaking or writing Spanish, or traveling in countries where Spanish is spoken. The format of the questions is illustrated for the categories of listening and reading.

Listening to Spanish (other than travel)

	Once a year or less	2–11 times per year	several times each month	several times each week
Radio	_____	_____	_____	_____
Television	_____	_____	_____	_____
Films	_____	_____	_____	_____
Conversation of others	_____	_____	_____	_____

Estimated average length of listening times _____

Please check whether the above answers apply:
1. For all years since your last Spanish course
2. For a period of time from approximately _____ to _____

Reading of Spanish

	Once a year or less	2–11 times per year	several times each month	several times each week
Newspapers	_____	_____	_____	_____
Magazines	_____	_____	_____	_____
Books	_____	_____	_____	_____
Correspondence	_____	_____	_____	_____

Estimated average length of reading times _____

Please check whether the above answers apply:
1. For all the years since your last Spanish course
2. For a period of time from _____ to _____ with the following significant changes: _____.

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Roediger Appointed Editor, 1985–1990

The Publications and Communications Board of the American Psychological Association announces the appointment of Henry L. Roediger III, Purdue University, as Editor of the *Journal of Experimental Psychology: Learning, Memory, and Cognition* for a 6-year term beginning in 1985. As of February 1, 1984, manuscripts should be directed to

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West Lafayette, Indiana 47907

Manuscript submission patterns for the *Journal of Experimental Psychology: Learning, Memory, and Cognition* make the precise date of completion of the 1984 volume uncertain. Therefore, authors should note that although the current editor, Richard M. Shiffrin, will receive and consider manuscripts until January 31, 1984, should the 1984 volume be completed before that date, manuscripts may be redirected to Roediger for consideration in the 1985 volume.