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Remembering the Street Names of One's Childhood Neighbourhood: A Study of Very Long-term Retention

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Life-span retention of street names was studied in a sample of former students of a Dutch elementary school. Participants were requested to recall the street names of their childhood neighbourhood and indicate their position on a map. In addition, information was gathered concerning (a) the extensiveness of the original learning experience, (b) its elaborateness, and (c) the amount of interference from similar materials occurring between original learning experience and time of recall. Retention intervals varied from 0 to 71 years. Amount of exposure, elaborateness of learning, and retroactive interference all contributed to the memorability of names. In addition, the forgetting curve showed a permastore effect (Bahrick, 1984), suggesting that memory for non-schematic, incidentally learned material is subject to processes of forgetting similar to those that affect intentionally learned material, such as subject-matter acquired in school.

Do you remember your childhood neighbourhood? The neighbourhood where you roamed the streets with your friends, played hide-and-seek, and learned how to ride a bike? The neighbourhood where you walked to school with your younger brother and hung-out in front of the neighbourhood café? Do you recall the places where you lived through these events? In particular, do you remember the names of the streets on which these events happened?

An answer to this last question may depend on a number of issues, such as how long ago you left your neighbourhood, how intensively you roamed its streets, and to what extent you actually needed the names of the streets to find your way. The study of factors influencing the recollection of everyday experiences stored in a distant past, is the study of ecological, or very long-term, memory (Conway, Cohen, & Stanhope, 1991; Squire, 1989). This is a branch of cognitive psychology that takes a particular interest in how people encode experiences in natural contexts (rather than sample experiences in the psychological laboratory) and how long these encoding episodes survive. Processes of forgetting are studied on a time scale of decades rather than hours or days. It may be clear that this type of research potentially has implications for both our basic understanding of learning and forgetting in the real world, and the application of psychological knowledge to the solution of real-life problems in education, or elsewhere that memory-based performance is important.

Despite their potential, studies of very long-term memory have been limited in mumber (e.g. Conway, Cohen, & Stanhope, 1992; Bahrick, Bahrick, & Wittlinger, 1975) The reasons for this relative neglect by memory researchers are both methodological and practical. The long time spans involved in long-term memory research, in some cases up to 60 years, make it difficult to use traditional laboratory methods. Consequently,

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investigators have only limited control over the conditions under which material was learned, the length of the retention interval, or the amount of rehearsal during this retention interval. In addition, groups of participants who have learned the material under similar circumstances are hard to find. And third, researchers are almost exclusively confined to the use of cross-sectional designs rather than longitudinal ones because of the time spans involved. It may, therefore, come as no surprise that findings emerging from the studies conducted have not yet provided unequivocal explanations for the processes guiding the acquisition and retention of knowledge over longer time spans.

This article describes a study into long-term retention of street names learned during childhood. The intention was to contribute in two ways to our understanding of how knowledge is acquired in everyday life and retained over long stretches of life. First, the study was intended to clarify the nature of forgetting under these circumstances. Different forgetting curves have been found in very long-term retention studies; some demonstrating rapid decay, others showing high levels of memory performance over long retention intervals. Some authors suggest that the nature of the learning experience itself is responsible for these different paths of decay. Formal, school-based learning would lead to a pattern of forgetting different from informal learning in everyday settings (Conway et al., 1992). Second, conditions that influence retention were examined. The study tested whether forgetting of naturalistically acquired material can be predicted from the same factors that govern laboratory forgetting, notably the amount of exposure to the material, the elaborateness of the learning experience, and retroactive interference. Before turning to the findings, the extant literature will be reviewed with an eye to the factors influencing learning and very long-term retention in natural contexts.

VERY LONG-TERM RETENTION OF KNOWLEDGE ACQUIRED THROUGH SCHOOLING

Bahrick and his co-workers have conducted several cross-section studies to investigate the life-span retention of knowledge acquired in the context of instructional processes (Bahrick, 1984; Bahrick & Hall, 1991). In these studies, large numbers of participants were tested on the retention of knowledge acquired at different times in the past. Information regarding the length of the retention interval, the degree of original knowledge, and the amount and type of rehearsal during the retention interval was obtained from various sources. These sources included archival records and questionnaires administered to the participants. To examine individual-differences variables in life-span memory, Bahrick used multiple regression techniques.

In one of these studies, Bahrick (1984) investigated the retention of knowledge of Spanish learned in high school or college over a period of 50 years. Retention was predictable from the level of original training. People who had studied Spanish more extensively, remembered more. Bahrick found that the retention curve obtained comprised three distinct components. Part of the originally acquired information was lost rapidly in the first six years after acquisition. The remaining part—almost 60% of the knowledge originally acquired–survived more than 25 years in an almost unaltered state, and most of that knowledge was retained for more than 50 years in spite of the fact that it had never been used or rehearsed (although only for those who took more than one course in Spanish). According to Bahrick, this knowledge had entered a state of "permastore". He argued that once knowledge has stabilised in this permastore condition, it becomes resistant to forgetting over very long periods of time. The last part of the curve again showed a rapid decline of knowledge. Because this part described performance after retention periods of 40–50 years and involved participants in their 60s or 70s, this finding may be attributed to age-related memory decay.

Bahrick and Hall (1991) investigated retention of mathematics over a period of 50 years. Again, it was found that level of original knowledge determined retention. Those who studied mathematics to an advanced level showed very little forgetting, whereas those who had not done so showed a steady decline. Amount of practice turned out to be the crucial factor. If rehearsal or exposure is extended over several years, performance levels remain stable for half a century without the benefit of further practice. However, if the same content is acquired over a shorter period, performance tends to decline rapidly and continuously. Bahrick and Phelps (1987), investigating memory for English–Spanish word pairs, reported a similar finding. They found that two variables predicted the likelihood of permastore retention eight years after the learning episode: the spacing of the original learning sessions and the number of presentations required for acquisition. Second, retention losses were relatively unaffected by individual-differences variables such as actual grades obtained on courses and more general measures of intellect.

In a critique of the permastore concept, Neisser (1984) argued that there is no need to assume the existence of a separate memory store (or state) for knowledge surviving long retention intervals to explain Bahrick's findings. These findings can equally well be explained by theories that assume that students acquire abstract cognitive structures, or schemata, from which they generate answers on the questions posed to them. Very long-term memory is, in Neisser's view, not the recall of well entrenched facts, but the reconstruction of this knowledge from more abstract structures that, because of their coherence and abstractness, are resistant to forgetting. However, Conway et al. (1992), in a study of long-term retention of cognitive psychology knowledge acquired as part of a university degree, found that participants' memory for isolated facts was better than their memory for conceptual relations. They concluded that their findings support Bahrick's permastore concept rather than Neisser's schema-theoretical notions of very long-term memory.

VERY LONG-TERM RETENTION OF KNOWLEDGE ACQUIRED THROUGH INFORMAL, EVERYDAY EXPERIENCE

In addition to the study of long-term survival of knowledge acquired through formal education, efforts have been made to understand to what extent knowledge acquired through informal, everyday experience is retained. Squire (1989), for instance, studied memory for television programmes. A test was presented to participants that sampled television programmes that had occurred during a single year and were broadcast from 1 to 15 years ago. Updated versions of the test were administered annually over a period of nine years. Finally, a forgetting curve was calculated by superimposing the results from the nine tests. It was found that forgetting in very long-term memory was gradual and continuous for many years after learning.

Stanhope, Cohen, and Conway (1993) investigated very long-term retention of the contents of a novel. They reported that proper names were forgotten more rapidly than role knowledge. However, the retention curves of both types of knowledge initially showed a brief decline, after which they remained stable.

Bahrick, Bahrick, and Wittlinger (1975) required participants to recall names and faces of classmates from high school. The materials used were taken from yearbooks. The retention interval since graduation ranged from two weeks to 57 years. Participants recalled on average 14% of the total number of possible names to be remembered, equalling about 40 names. However, recall performance declined in a negatively accelerated fashion over a period of 50 years. A similar study, reported in Bahrick (1984), of teachers' retention of names and faces of former students, demonstrated continuous and gradual forgetting.

In a study particularly pertinent to the research presented here, Bahrick (1983) investigated the learning of spatial information about a university town (Delaware) acquired during a four-year period of residence, and the subsequent loss of this information over a period of 46 years. The study involved 851 individuals: 275 were undergraduate students at a mid-west university and were tested to obtain data concerning the acquisition of a cognitive map of the town; 576 were alumni of the university and were tested to obtain data concerning the retention of that knowledge. Some of the alumni were tested on the occasion of a visit or at meetings in other cities. Others self-administered the tests at home and returned them by mail. The test consisted of five sub-tests: free recall of street names, free recall of landmarks, visually cued recall, verbally cued recall, and matching of names, landmarks, and places. Using a method that he called "cross-sectional adjustment", Bahrick found that almost all of the street names originally learned were lost rapidly within 10 years and it mattered little whether free recall, visually cued recall, or recognition-matching tasks were used. This was true to a lesser extent for the retention of landmark names. Information about landmarks was forgotten more slowly and showed a constant decline over the whole retention interval.

The studies reviewed so far afford a number of tentative conclusions about factors that control very long-term retention of material learned. The first is that the amount of time that people are exposed to the material—and the spacing of the learning episodes—are important determinants of how well it will be remembered. Second, materials studied at an advanced level seem to follow a forgetting curve characterised by initial fast forgetting followed by a long period, sometimes more than 50 years, during which essentially no further forgetting takes place. Materials studied less extensively show steady and often fast decay, akin to the kind of forgetting that occurs in the laboratory. Third, forgetting of materials acquired through informal, everyday exposure tends to be gradual and continuous. It is presently not clear which factors govern these different patterns of retention (Conway et al., 1992). The studies conducted so far seem to imply that material learned intentionally may be stored differently from material stored incidentally, such as everyday experiences. However, Bahrick and Hall (1991) have demonstrated that, under shallow learning conditions, intentionally learned materials are also forgotten following a gradual and continuous curve, much like incidentally acquired materials. An alternative assumption may be that autobiographical memories, such as names and faces of classmates, street names, and names of popular television series, tend to be arbitrary and do not contain inherent structure that would support retrieval. Semantic knowledge, such as mathematics or Spanish, tends to become more highly abstracted and more tightly integrated than autobiographical knowledge, thus ensuring adequate retrieval or appropriate reconstruction when needed. This is a version of Neisser's (1984) proposal. We have already seen, however, that isolated facts are in fact sometimes better retained than conceptual, schema-based information learned in a course (Conway et al., 1992).

In this article, we propose that no constitutive differences exist between the retention of autobiographical knowledge, such as memory for street names, and the retention of semantic knowledge, or between non-schematic and schematic knowledge. We assume here that very long-term retention of knowledge acquired in a distant past is a function of three processes that play a role in laboratory studies of forgetting as well: (a) the extensiveness of the original learning experience in terms of the amount of time that participants were in a position to learn the information (formally or informally) or were simply exposed to it; (b) the richness of the learning experience; and (c) the amount of interference from similar materials occurring between original learning experience and time of recall. We assume that the more extensive and richer the original learning event, and the less the interference of similar events, the greater the chance that a core of knowledge remains available over long stretches of life. If exposure is limited, learning shallow, and retroactive interference high, retention would be poor to begin with and would decline in a continuous fashion. Under conditions of extensive and elaborate learning and low interference, however, much knowledge, autobiographical as well as semantic, may be retained in a permastore fashion.

To test these hypotheses, we decided to replicate and extend Bahrick's (1983) study of memory for street names. This study seemed particularly suited to our purposes because street names, like names of persons, are arbitrary and usually do not have an underlying structure that would support retrieval. Second, long-term retention of the names learned in Bahrick's study had been poor: students while still living in the town recalled 13 out of 20 street names tested. However, alumni ended up after 10 years with recall scores no higher than 20% of the senior students' scores, equalling 2.6 street names. Thus, the course of forgetting emerging from this study was continuous. Third, although Bahrick's college students had spent four years in the town, their actual experience with its streets was fairly limited. They spent most of their time on campus and they covered larger areas mainly by car. Finally, the layout of the town was similar to that of many American cities: grid-like with streets running parallel in north–south or east–west directions. There may be no particular need to rely on street names while finding your way in cities that have this kind of street plan, as anybody who has ever asked for directions on Manhattan has experienced. "To get to the Empire State Building, you simply walk three blocks north and two blocks west." In European cities with their crooked little streets and alleys, directions can often only be given with reference to street names, otherwise one tends to end up nowhere: "To get to the Dam in Amsterdam, follow the Lauriersgracht until you get to the Prinsengracht; go slightly to the left, then cross the bridge over the canal to the right into the Reestraat. The Reestraat changes into Hartestraat after 100 metres. Cross the Spuistraat and keep slightly left." Under conditions where knowledge of street names is necessary to find your way, initial learning may be better. In addition, the *nature* of the experience with the streets in your city may play a role. For instance, if you only use your knowledge of the street plan for getting a pizza by car once in a while, your experience with the city may be more superficial than if you play on its streets, have friends living all over the neighbourhood, go to school following the same or different routes, and explore the town on foot rather than by bike or car. The intensity and multiformity of the interaction with one's neighbourhood might contribute to a more elaborate processing of street names and, hence, to better recall over long stretches of life. Finally, one could not preclude the possibility that moving quite often from city to city, and having to learn new street plans every time, may interfere with the knowledge originally acquired about the target neighbourhood. Bahrick (1983) does not provide information about his participants' moving patterns, but US citizens are known to move more often than Europeans from one city to another in their lifetime, if this is required for finding a new job. This may in particular be the case for the more highly educated, which describes Bahrick's participants.

An additional reason to study memory for street names was that, unlike learning of Spanish or mathematics, the content of what could have been learned originally can be established with absolute certainty, even after 60 years have passed.

The present study was conducted with regard to a 48-street fairly self-contained neighbourhood of a medium-sized city in the Netherlands. Participants were all former students of an elementary school situated in that neighbourhood and most of them had lived at walking distance from the school. They were sent a questionnaire inquiring about various aspects of their life in that neighbourhood. They were asked how long they had lived there, how often they had returned; where they used to play; how they would go to school and by what kind of transportation, and how many times they had moved since having lived there. In addition, the participants were required to recall as many names of streets of the neighbourhood as they could and indicate their position on a map. Multiple regression techniques were used to estimate the size of the influence of the various determinants on memory performance and to provide an uncontaminated estimate of recall performance as a function of retention interval.

METHOD

Participants

A total of 211 former pupils of an elementary school of the "Molenberg" neighbourhood, part of the city of Heerlen in the Netherlands, participated in this study: 172 male and 39 female. The larger group of male participants is due to the fact that until the 1970s the school was a Roman Catholic boys' school. Forty-five percent of the participants still lived in Heerlen. The ages in the total group of participants ranged from 11 to 79, with an average age of 44.68 and a standard deviation of 18.01. Participants turned out to be fairly well distributed over the various 10-year age groups, with an average of 30 per group. The exception was the 71–80 age group which consisted of seven participants.

Materials

The questionnaire consisted of 33 questions and the recall task. To complete the recall task, participants were provided with a copy of a map of the Molenberg neighbourhood. All 48 street names had been removed from the map and replaced by numbers. A cross on the map marked the spot where the school was situated. participants were also provided with an answer sheet listing the 48 numbers referring to the streets to be recalled. Participants were required to list all names remembered next to the numbers corresponding with those on the map. The questionnaire further inquired about (a) personal data, such as age, gender, health, and life styles that may influence memory; (b) where people had lived and for how long; (c) how often they had moved to other neighbourhoods or cities; (d) how often they had returned to the Molenberg neighbourhood and for how long; (e) where they usually played; at home, in the garden, on the streets; (f) whether they had friends living in the neighbourhood and if so, where these friends lived; (g) what means of transport were used while going to school (bike, car, bus, foot); (h) whether the same or different routes were taken while going to school; and (i) whether they were accompanied by others while going to school and if so, whether the company was older, younger, or the same age. The Appendix displays an English translation of a sample of relevant questions.

Procedure

A total of 700 people were chosen at random from a database consisting of 1700 names and addresses of former students of the school. Participants were sent a package consisting of the questionnaire, a letter asking for their participation, a postage-paid return envelope, and a pen. Participants were asked to fill in the questionnaire and return it by using the postage-paid envelope. Moreover, participants were instructed to complete the questionnaire at their own speed and were requested not to use any means to look up the answers. After a period of four weeks a total of 245 participants had returned the questionnaire, being a response rate of 35%. Although this response rate is typical for most questionnaire-based memory studies, the responses of our volunteers may not be entirely representative for the population surveyed. Questionnaires in which some questions had not been completed and those of participants not complying with the instructions were removed from the analysis.

Scoring

Measures of (a) extensiveness of exposure to the neighbourhood, (b) richness of the experience, (c) amount of interference, (d) retention interval, and (e) recall of street names were calculated from the participants' answering patterns. In some cases, these measures were based on a combination of answers. In addition (f) age, being an important covariant of some of the other variables, was recorded.

Exposure Level. Exposure level reflects the total amount of time participants were exposed to the neighbourhood during their life. Participants were hypothesised to have been exposed to the neighbourhood from their childhood years and during visits after having moved to a different city or neighbourhood. First, the total amount of time the person lived in the Molenberg neighbourhood was calculated. Some participants lived there only during their childhood years; others left for studies elsewhere but returned; a third group was still living in the neighbourhood when questioned; and a fourth group never lived there and only went to school in the neighbourhood. Second, participants were asked to provide an estimate of the total amount of time they had spent in the neighbourhood visiting family or friends, after having moved out. Exposure level was then calculated as the sum of these two values, expressed in mumber of years and parts thereof. See the Appendix for the original questions from which these indices were deduced.

Richness of the Learning Experience. Richness of the original learning experience was defined as the multiformity of ways in which participants, during childhood, had engaged in activities that might have led to learning the names of the streets in their neighbourhood. Three indicators of richness of the learning experience were distinguished: playing patterns, transport to school, and routes taken to school. *Playing patterns* was a composite score based on where one used to play and where friends lived in the neighbourhood. This score was higher if participants indicated that they played in the streets most of the time and had friends living elsewhere in the neighbourhood. An indicator of *transport to school* was calculated by combining questions on means of transportation and on accompanying persons. If participants indicated having gone to school on foot, alone, or in the presence of a younger person, the score was higher. Different *routes taken to school* led to a higher score than always taking the same route. The assumption here is that these conditions would optimise the chance that learning of street names would take place in different kinds of ways, enabling multiple redundant retrieval paths to occur in memory.

Amount of Interference. Amount of retroactive interference of similar learning episodes on the original one was estimated by the number of times people had moved to other neighbourhoods or cities.

Retention Interval. The retention interval was defined as the total number of years (and parts thereof) that participants were *not* exposed to the Molenberg neighbourhood since they last lived there.

Recall of Street Names. This measure was the total number of names correctly recalled. In some cases, participants came up with a correct name but assigned it to the wrong street on the map. The latter responses were excluded from the final score. More lenient scoring criteria did not lead to different outcomes, however.

Age. Age was recorded in number of years.

Statistical Analysis

Multiple regression analysis was carried out on the data with number of streets accurately recalled as dependent variable, and exposure level, indicators for richness of original acquisition, interference, retention interval, and age as independent variables. Based on earlier studies by Bahrick and his colleagues (Bahrick, 1983, 1984; Bahrick & Hall, 1991), it was assumed that the relationship between memory performance and retention interval may not be linear. Therefore, quadratic and cubic terms of the original retention interval variable were also included in the multiple regression analysis. See Bahrick and Karis (1982) for methodological details on these and related issues. To prevent collinearity between the three polynomial terms, retention interval was first centred before computing its quadratic and cubic term; that is, the sample mean of the retention interval was subtracted from each individual retention interval (Kleinbaum, Kupper, & Muller, 1988). This regression approach allows for the estimation and testing of the effect of each independent variable on recall, corrected for all other independent variables in the regression model. In particular, it allows for the estimation of the "pure" forgetting curve as a function of time passed. Keeping constant all independent variables in the regression equation as estimated from the data except retention interval, a recall score is obtained as a (polynomial) function of time passed only:

$$\text{Predicted recall score} = B_0 + B_1 * X_0 + B_2 * X_2 + B_3 * X_3 + C \qquad (1)$$

where X_0 is the centred retention interval, and X_2 and X_3 are the quadratic and cubic terms of this variable. The raw regression weights B_0, B_1, B_2, B_3 are estimated by multiple regression analysis including all covariates, and C is the total effect of all covariates obtained by inserting their respective sample means in the regression equation. Outcomes using this methodology are functionally equivalent to those presented in Bahrick's contributions (Bahrick, 1983, 1984; Bahrick & Hall, 1991).

RESULTS

Multiple Regression on Recall for Street Names

Table 1 displays descriptive statistics of the variables involved. Table 2 summarises the outcomes of the multiple regression analysis using recall as the dependent variable and the other variables as the independents.[1] The multiple R was equal to .64 and R^2 equalled .41. These findings imply that 41% of the variance in recall is explained by the variables included in the analysis, which is adequate given the limitations of questionnaire data. By comparison, Bahrick (1983) found approximately 39% of his street name recall data explained by the variables involved. Retention interval turns out to be a major determinant of forgetting, as has also been demonstrated in similar studies. This applies to linear, quadratic, and cubic components alike, suggesting that forgetting under the conditions of the present study is nonlinear. Age, playing behaviour, routes to school, and having moved to other neighbourhoods or cities, all contribute to recall performance. However, the regression coefficient for transport was not significantly different from zero,

TABLE 1
Means and Standard Deviations of the Variables Included in the Study

	M	*SD*
Recall	17.48	12.55
Age	44.18	18.12
Exposure	20.36	16.52
Playing patterns	2.71	.63
Transport to school	2.90	2.90
Routes to school	1.67	.47
Interference	2.62	3.83
Retention interval (Retention)	20.19	18.88
Squared Retention (Retention2)	345.29	328.98
Cubic Retention (Retention3)	2610.51	15815.35

TABLE 2
Summary of Multiple Regression Analysis for Variables Predicting Recall of Street Names

Variable	*B*	*SE B*	β	*t*
Age	.31	.06	.44	5.17***
Playing behaviour	2.74	1.22	.14	2.25*
Routes to school	5.44	1.59	.20	3.42***
Transport to school	2.75	1.97	.08	1.39
Moved to other cities	–2.86	1.21	–.15	–2.26*
Retention	–.31	.09	–.46	–3.41***
Retention2	.01	.01	.29	2.37**
Retention3	–.06	.02	–.41	–2.37**
Constant	–4.67	6.70		–.70

$^*P < .05$; $^{**}P < .01$; $^{***}P < .001$.

[1] Exposure was not included in the analysis because exposure, retention interval, and age are mutually dependent, exposure being the complement of retention. If age and retention interval are known, exposure is known.

indicating that transport to school does not make a unique contribution to the prediction of recall.

Memory for Street Names as a Function of Retention Interval

Figure 1 displays the actual recall of street names as a function of retention interval, averaged for 10-year retention intervals. Memory for names of the streets of one's childhood neighbourhood clearly cannot be described by a theory that predicts continuous and gradual forgetting. Forgetting seems to be rapid in the first 5 years, but then stabilises for more than 40 years after the initial learning experience. The distribution of scores found in this study appears to be similar to those found by Bahrick (1984), Bahrick and Hall (1991), and Conway et al. (1992), supporting the idea that a large part of the information is retained almost permanently. The smooth curve represents predicted recall under the assumption that factors other than retention interval have been held constant. As can be seen, predicted recall is roughly equivalent to observed recall and follows a similar curve, demonstrating that the permastore effect in the observed data cannot be attributed to the influence of contributing independent variables other than retention interval.

Memory for Street Names as a Function of Exposure

Exposure was the total amount of time that a participant had lived in the Molenberg neighbourhood or otherwise had been exposed to it. Figure 2 depicts memory performance as a function of years of exposure. As was expected, exposure plays an important role in memory performance. Participants who had been exposed to the environment more, remembered more street names. (The apparent decline after 70 years of exposure is based on only very few data points.) One-way analysis of variance confirms the visual impression: $F(8, 194) = 8.76$, $MSE = 119.06$, $P < .0001$.

Playing Patterns, Transport, and routes to School

One-way analyses of variance were conducted to further investigate the role of these richness-of-experiences variables. These analyses were conducted under the assumption that the influence of all other variables was roughly constant or random. Different playing patterns led to significant differences in memory performance: $F(2, 195) = 4.13$, $MSE = 153.00$, $P < .01$. The more participants played as children in the streets of their neighbourhood and the more they had friends living elsewhere in that neighbourhood, the better their memory in later years. The same applies to the influence of means of transport: participants who, as a child, went to school on foot and alone or with a younger child, tend to do better than those who used other means of transport, accompanied by older persons; $F(2, 202) = 3.46$, $MSE = 153.98$, $P < .05$. Those who used various routes to school

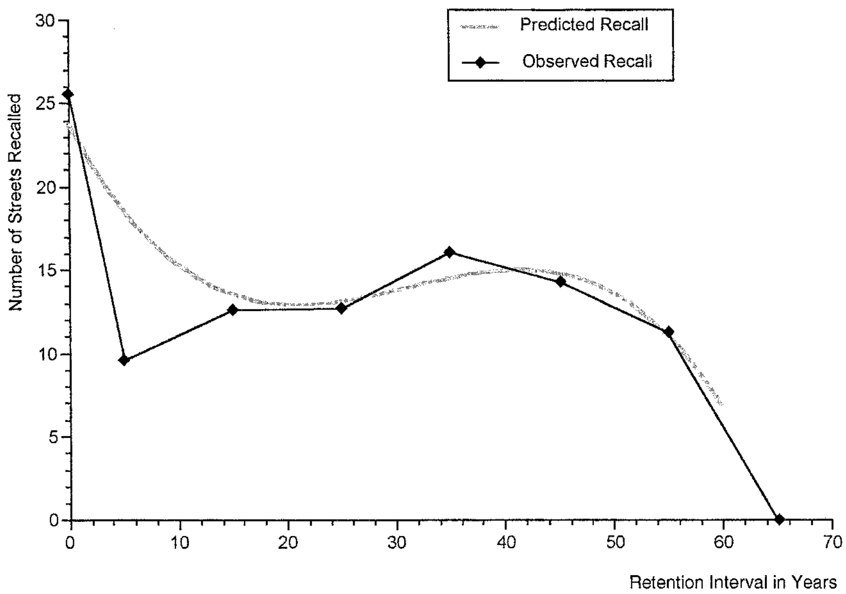

FIG. 1. Observed number of street names recalled as a function of retention interval, represented by the discontinuous line. Predicted number of streets recalled is represented by the smooth curve.

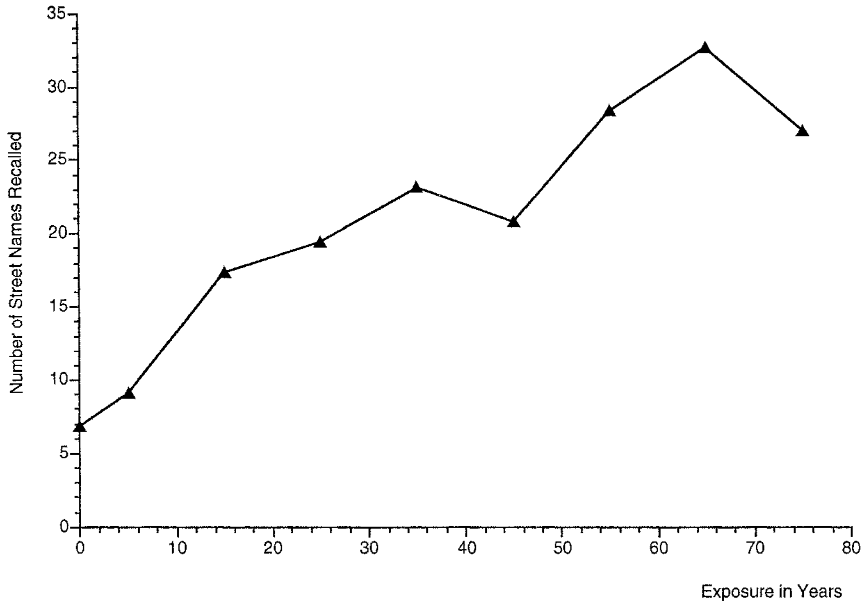

FIG. 2. Number of street names recalled as a function of number of years of exposure to the neighbourhood.

rather than always the same route also did generally better: $F(1, 201) = 13.64$, $MSE = 149.12$, $P < .001$.

Interference

There was considerable variability among participants in the number of times they moved. About 25% never moved, whereas one of the participants indicated having moved 40 times. Figure 3 displays recall of street names as a function of the number of times moved. One-way analysis of variance confirmed the visual impression of the graph; the more participants had moved; the more forgetting had taken place: $F(4, 201) = 6.98$, $MSE = 141.10$. $P < .0001$.

DISCUSSION

Memory for street names plays an important communicative role in everyday life. It enables people to talk about locations and to locate scenes of action or events. For instance, referring to a particular street in which a car accident has hap-

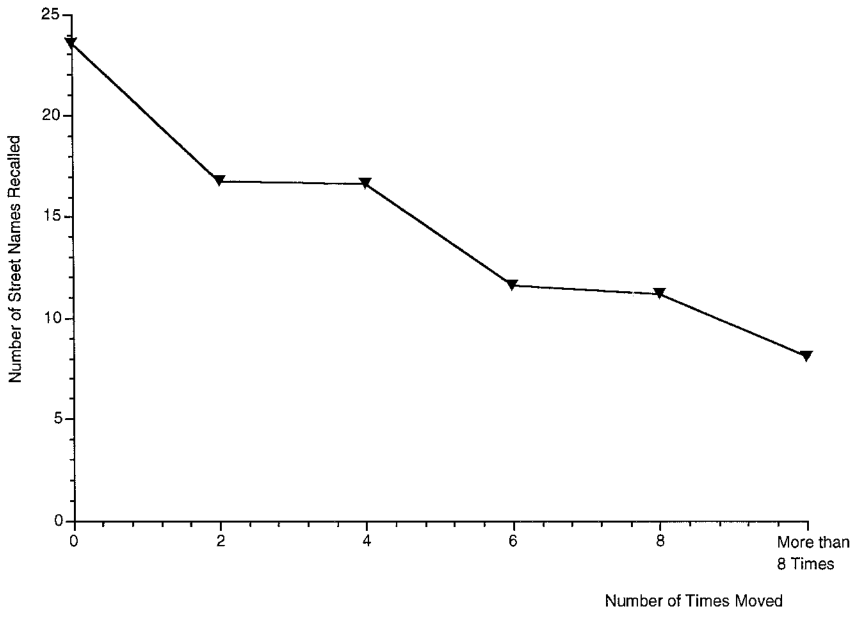

FIG. 3. Number of street names recalled as a function of number of times participants hand moved to other neighbourhoods or cities.

pened will contribute to the listener's understanding of the accident's context. Street names, in addition, function as shorthand, enabling people to instruct other people where to go and how to get there. Children may learn street names largely through everyday interaction with their parents and peers, and as a function of their use. Encoding of some street names may take place in multiple ways, in particular if these streets play diverse roles in the life of the learner. For instance, on one of the streets in the Molenberg neighbourhood, the elementary school, most shops, and the neighbourhood cafés were situated. Almost every participant recalled its name even after long retention intervals. Some streets, on the other hand, are simply never visited or referred to, and, hence, will not be remembered. Even those participants in our study who still lived in the neighbourhood recalled on average no more than 25 out of 48 names, performing less well than Bahrick's senior students.[2]

Permastore Effect in Street Name Recall

The forgetting curve for street names found in the present study followed the pattern found in studies of school subjects such as a foreign language (Bahrick, 1984), mathematics (Bahrick & Hall, 1991), or cognitive psychology (Conway et al., 1991). A relatively short period of loss of names was followed by a period of 40 years in which essentially no forgetting took place. Performance during this retention period was at 60% of the performance of those still living in the neighbourhood. This finding implies that the nature of forgetting is not an inherent function of the materials learned. Some authors have suggested that, in contrast to school subjects, informally learned information such as names of streets or television broadcasts tends to show gradual and continuous loss over the years because these kinds of knowledge are essentially non-schematic (Conway et al., 1992). The present study demonstrates that this assertion is not true. Although streets names in the neighbourhood studied were largely arbitrary and therefore could not be reconstructed from the structure in which they reside (e.g. a map, mental or real) or deduced from other cues that have inherent structure,[3] their recall showed a pattern similar to the recall of schematic and non-autobiographical knowledge such as mathematics or psychology concepts. Neisser's (1984) assumption that most knowledge retrieved after long retention intervals is not so much directly recalled but reconstructed on the basis of schemata that survive in long-term memory because of their inherent structure is therefore not correct. The findings presented here demonstrate that materials lacking this underlying structure may nevertheless survive retention intervals as long as 50 years.

According to Bahrick (1984), the permastore affect is the result of massive overlearning of material, both in terms of the length of exposure and the spacing of the learning experience. He provides evidence that for part of the knowledge of Spanish no forgetting at all occurred, whereas the remaining part decayed over a period of six years. There was no evidence for loss of knowledge with slower decay rates, for instance over periods of 10 or 15 years. This suggests that knowledge in his subjects was indeed in one of two discrete states: either in a frail, decay-prone state or in a state immune to forgetting. Only under conditions of overlearning would the permastore effect occur; shallow learning would lead to the construction of a knowledge base that obeys common laws of forgetting. To check whether this prediction also holds for our data, we selected those participants who indicated that they had never lived in the Molenberg neighbourhood or did not play in the streets as a child. The resulting forgetting curve indeed displayed fast and almost complete forgetting in the first five retention years. This finding is in line with those of Bahrick (1984), Bahrick and Hall (1991), and Conway et

[2] In addition, the difficulty level of the recall task itself may have contributed. Many of the streets in the particular neighbourhood were named after obscure Dutch 19th-century writers such as Justus van Maurik and Jacob van Lennep.

[3] Brédart and Valentine (1998) have demonstrated that arbitrary proper names are far more difficult to retrieve than descriptive names, probably because they convey little information about the entities to which they refer. See also Cohen and Burke (1993). However, names of streets need not always be arbitrary. In some cities, streets are numbered, e.g. 1st Street, 2nd Street, and knowing which street is 1st Street helps one to deduce which street is, for instance, 5th Street. Bahrick (1983) cites a study by Devlin that provides illustrative data in this respect. Her students were able to identify more than 40 streets after only three months of residence, clearly many more than the numbers of street names recalled in Bahrick (1983) and in the present study. According to Bahrick this difference is almost certainly due to the alphabetical, numerical, and related topographical ordering of the street names in the city involved (Idaho Falls).

al. (1991), who demonstrated gradual and continuous forgetting among students who did not reach advanced levels of training.

Although now well established as an empirical phenomenon, the permastore effect does however provide serious difficulties for existing theories of memory, in particular because of its assumption that knowledge must exist in one of two discrete states. It is certainly possible to imagine names of some streets to be so well entrenched in an associative network of experiences gathered in these streets that knowledge remains available throughout one's life span. People for the same reason do not forget their mother's name. But why would street names only a tiny bit less entrenched in multiple experiences be gradually forgotten? What makes a piece of knowledge cross the border of oblivion to become immune to forgetting? It is clear that research is much needed to answer this question.

Richness of the Learning Experience

One of the more interesting findings of the present study was that not only did the length of the learning experience, in terms of exposure, influence the memorability of street names but also the *richness* of the original experience. Richness of an experience was defined here as the multiple different ways in which that experience becomes encoded in memory. We were able to demonstrate that playing patterns, means of transport through the neighbourhood, and routes taken to school during childhood all affected memory, although transport did not show a unique contribution to performance in multiple regression analysis, possibly because its distribution is skewed; most participants tended to go on foot. Participants who, as a child, played more on the streets, had friends living elsewhere in the neighbourhood, walked to school alone or in the company of younger children, and tended to use different routes to school, remembered more and over longer stretches of life than did those who engaged in these activities to a lesser extent. This finding suggests that, in addition to the length of a learning experience and its spacing, the *quality* of learning may also play a role. In laboratory experiments, the effects of elaborative encoding are well established (e.g. Craik & Lockhart, 1972). Our demonstration of a similar phenomenon in very long-term retention of street names is, to our knowledge, among the first that documents the lasting effects of rich encoding in naturalistic contexts. This rich encoding of information may be a major reason that our findings are at variance with those reported by Bahrick (1983). After 10 years, Bahrick's college graduates remembered hardly any street names of the city of Delaware in which their university was located. However, these students' exposure to these streets was far more limited in time—4 years of residence versus an average of 20.36 years—and far less intimate than the exposure that our students received. First Bahrick's students spent most of the time walking in a relatively small area of city and campus; the rest of the city was travelled by car. Second, the area covered by the Molenberg neighbourhood was much smaller than the university town studied by Bahrick, so most of the distances within the neighbourhood could be travelled by foot. Third, the participants in Bahrick's study were young adults who came from elsewhere, whereas in the present study, participants were mostly born in the neighbourhood and learned the names of the streets during their early childhood. Possibly, children interact more intensely with the environment through playing and travelling by foot than students do.

Retroactive Interference

Another phenomenon extensively documented in the memory lab is retroactive interference. New and similar learning experiences influence the memorability of previous learning, probably because the originally learned items lose some of their distinctiveness (e.g. Keppel & Underwood, 1962). In the present study, moving and subsequently living in new neighbourhoods had a definitive effect on memory of the childhood neighbourhood. The more participants had moved, the more interference occurred. Figure 3 suggests that learning new street patterns and their accompanying names makes the original learning experiences less retrievable proportional to the number of times moved. This can hardly be an effect of the similarity of street names in new towns to those of the neighbourhood of origin. Unlike US cities, Netherlands towns tend to provide their streets with quite unique names, diminishing the chance that one of the participants in our study ever lived in a neighbourhood with names similar to the one that one moved from (see also footnote 3). Therefore, a lack-of-distinctiveness explanation for the retroactive interference found in this study seems less likely. Perhaps learning a new street plan itself rather than simply learning the names of the streets interferes with previously learned street plans (and, hence, with their names). Alternatively, assuming that the pool of street names learned has become greater, the retrievability of the individual exemplars required may be smaller.

If retroactive interference exists in naturalistic contexts, proactive interference cannot be excluded as another possible influence in very long-term memory. I have no difficulty remembering the street where I spent my childhood years, but it takes me some time to identify the name of the street to which I moved from my dormitory in my university town, even though learning the latter name has occurred more recently. Proactive and retroactive interference may have played a role in the performance of Bahrick's (1983) alumni as well. The alumni learned the street plan of Delaware when they were aged around their 20s and may have moved a number of times before and after their university years. The combination of proactive and retroactive interference may have influenced their performance negatively. This hypothesis is of course tentative because Bahrick's study does not provide information that would enable a test.

CONCLUSION

In conclusion, the present study has demonstrated that very long-term memory is subject to processes of forgetting similar to those found in laboratory studies of memory. In addition to amount of exposure to the material to be learned (a variable whose effectiveness has been documented in most very long-term retention studies), richness of encoding, and retroactive interference turned out to be determinants of memory over the life span. These findings at least reinforce the hope for a unified theory of memory, accounting for both the memorability of short-term laboratory learning experiences and longer-term memory in everyday life, a hope that has met with some scepticism in the recent past (e.g. Neisser, 1982).

In addition, the study has demonstrated that autobiographical, arbitrary, non-schematic material such as street names is subject to the same long-term memory processes as semantic and schematic knowledge, such as knowledge of mathematics (Bahrick & Hall, 1991) or cognitive psychology concepts (Conway et al., 1991). The permastore effect, replicated in the present study, should form a major challenge to memory researchers, in particular because its theoretical explanation is presently far from satisfactory.

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APPENDIX

Sample questions of the "Molenberg" questionnaire The numbering of the questions refers to the numbering of the full questionnaire. Answers to questions 3, 3a, 3b, 3c, and 6 were used to estimate the *level of exposure* to the Molenberg neighbourhood. *Playing pattern* was measured by a composite of questions 10, 16, and 17. *Transport to school* was estimated through summation of questions 8 and 9. *Routes to school* was measured by question 20.

3. Did you ever live in the Molenberg neighbourhood?
No (continue with question 4).
Yes.

3a. If yes, do you still live in the Molenberg neighbourhood?
No
Yes

3b. For how long have you lived in total (up till now) in the Molenberg neighbourhood?
.... years.

3c. Please indicate the age periods that you lived in the Molenberg neighbourhood and where you lived (fill in age periods and the name of the street).
From age ..... to age ..... I lived in .... (street name).
From age ..... to age ..... I lived in .... (street name).
From age ..... to age ..... I lived in .... (street name).

6. How often have you returned to the Molenberg neighbourhood after having moved?
Daily.
Weekly.
Monthly.
About .... times a year (fill in a number).
Once every .... years (fill in a number).
Never.

8. How did you go to school most often?
By foot.
By bike.
By bus or car.

9. Did you go alone or together with others?
Most often alone.
Most often with someone younger.
Most often with someone older.
Most often with someone the same age.

10. Where did you play?
Most often in the streets.
Most often in the garden.
Most often at home.
Elsewhere, namely ....

16. Did you have friends or family living in the Molenberg neighbourhood whom you visited regularly?
☐ No (continue with question 18).
☐ Yes.

17. If yes, did most of them live in your street?
☐ No, most of them lived elsewhere in the Molenberg neighbourhood.
☐ Yes, most lived in my street.
☐ No, I did live in the Molenberg neighbourhood myself.

20. Did you take different routes to school?
☐ No, the same route every time.
☐ Yes, different routes.