International Journal of Educational Psychology

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Date of publication: February 24th, 2013

To cite this article: Lieury, A. & Lorant, S. (2013). Encyclopedic Memory: Long-Term Memory Capacity for Knowledge Vocabulary in Middle School. *International Journal of Educational Psychology, 2*(1), 56-80. doi: 10.4471/ijep.2013.18

To link this article: http://dx.doi.org/10.4471/ijep.2013.18

IJEP – International Journal of Educational Psychology Vol. 2 No. 1 February 2013 pp. 56-80.

Encyclopedic Memory: Long-Term Memory Capacity for Knowledge Vocabulary in Middle School

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Abstract

This article is a synthesis of unpublished and published experiments showing that elementary memory scores (words and pictures immediate recall; delayed recall, recognition), which are very sensitive to aging and in pharmacological protocols, have little or no correlation with school achievement. The alternative assumption developed is that school achievement strongly depends on the long-term memory of scholastic knowledge (history, literature, sciences, maths, etc), called encyclopedic memory.

A longitudinal study from the grade 6 to the grade 9 of a cohort of eight classes of a French college, was undertaken in order to observe the implication of the encyclopedic vocabulary (i.e. Julius Caesar, Manhattan, Shangaï, Uranus, vector) in school performance. An inventory in the school textbooks gives approximately 6000 encyclopedic words in grade 6 to 24000 in grade 9. The encyclopedic storage capacity was estimated at the end of each year by a multiple-choice questionnaire with random samples of words (800 items; 8 subjects). The results show an estimation of 2500 words acquired at the end of grade 6, to 17000 at the end of grade 9. The correlations range from .61 to .72 between the score of encyclopedic memory and the average school grades.

Keywords: encyclopedic memory, long-term memory, capacity, knowledge, school achievement.

ISSN 2014-3591
DOI: 10.4471/ijep.2013.18

IJEP – International Journal of Educational Psychology Vol. 2 No. 1 February 2013 pp. 56-80.

Memoria Enciclopédica: Capacidad de Memoria a Largo Plazo para el Conocimiento de Vocabulario en la Escuela Media

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Resumen

Este artículo es una síntesis de experimentos no pubicados y publicados que muestran que los resultados en memoria básica (memoria inmediata de palabras y dibujos; memoria retardada y reconocimiento) que es muy sensible a la edad y a los protocolos farmacológicos tienen poca o ninguna correlación con el rendimiento escolar. La asunción alternativa desarrollada es que el rendimiento escolar depende fuertemente de la memoria a largo plazo o memoria escolástica (historia, literatura, ciencias, matemáticas, etc.), llamada memoria enciclopédica.

Se llevo a cabo un estudio longitudinal desde el sexto hasta el noveno curso de una promoción de ocho clases de una universidad francesa para observar la implicación del vocabulario enciclopédico (i.e. Julio César, Manhattan, Shangaï, Uranus, vector) sobre el rendimiento escolar. Un inventario en los libros de texto ofrece aproximadamente 6000 palabras enciclopédicas en el sexto curso y 24.000 en el noveno curso. La capacidad de almacenamiento enciclopédico se estimó al final de cada año con un cuestionario de respuestas múltiples con muestras de palabras al azar (800 ítems; 8 asignaturas). Los resultados mostraron una estimación de 2.500 palabras adquiridas al final del sexto curso y hasta 17.000 al final del noveno curso. Las correlaciones van de 0.61 a 0.72 entre el resultado en memoria enciclopédica y la media de las notas escolares.

Palabras clave: memoria enciclopédica, memoria a largo plazo, capacidad, conocimiento, rendimiento escolar.

ISSN 2014-3591
DOI: 10.4471/ijep.2013.18

Memory has always been considered important for academic achievement. But, knowing the variety of mnemonic mechanisms, it is not easy to ascertain which of them are concerned in school performance. Indeed, while some indicators of memory are very sensitive to ageing or to pharmacological protocols (Lieury, Trebon, Boujon, Bernoussi, & Allain, 1991; Allain, Lieury, & Gandon, 1993), they appear to be correlated only slightly or not at all with school results of pupils or students.

Standard Test of Memory (SM9) and Performance in the College

Thus, during studies of validation of a test intended for a pharmacological use (the SM9, "9 Scores of Memory": Lieury et al., 1991) experiments were carried out, one of which with middle school pupils. The SM9 is a test of memory conceived to evaluate tests of clinical pharmacology. It is a video test and is composed of 9 subtests of memory suitable for calculating fundamental memory scores : words and pictures, immediate and delayed recall; words, pictures, familiar and not-familiar faces recognition (Lieury et al., 1991) and lastly, a test of semantically organized recall (the only test which is presented on paper rather than on video).

These memory scores were correlated with the annual school grades averages in three subjects for 181 last-year middle school students of the French "Lycée" (average age, 17 years). As the correlations were almost null, we suspect that the grades were not comparable from one class to the other. Thus the school averages in these subjects were standardized. The correlations, however, were very weak, (see Table1) not exceeding .20, the majority being close to 0. What dominates, on the whole, it is the absence of relation between the elementary mechanisms of the memory, as measured by the SM9, and school performance.

One could think that the weak or negligible correlations are the result of an absence of fidelity in grades obtained in school (professors noting in a variable way amongst themselves and over time) but the school grades are in moderate correlation (.28 between maths and history/geography; and .34 between languages and history/geography),

which is more than they are with the elementary mechanisms of the memory, measured by this battery.

Table 1
Correlations between Scores of memory (SM9)and school averages in three subjects in middle school students (average age : 17 years; n = 181),*

	Maths	Foreign Languages	History-Geography
Immediate Recall of Pictures	-.17	-.08	-.00
Immediate Recall of Words	-.04	.01	-.05
Delayed Recall of Pictures	-.08	.02	.05
Delayed Recall of Words	.06	.09	.11
Organization	-.03	.03	.15
Recognition of Pictures	-.11	-.03	.00
Recognition of Words	-.20	.00	.03
Recognition of familiar faces	.08	.14	.06
Recognition of not familiar faces	.09	.04	.15

* The correlations are significant to .05 starting from r = .13 (n = 181).

Reasoning and School Performances

It is probably because of the lack of predictability of this type of memory tests (short-term memory or rote learning) that tests of reasoning were more widely used. However, validation studies of these tests of reasoning also give medium or weak correlations. The most complete French research is unknown as it is related in an unpublished thesis (N'Guyen Xuan, 1969; see Lieury 2012). Anh N'Guyen Xuan built 12 tests of reasoning (15 in other studies), 4 of verbal reasoning, 4 of numerical reasoning and 4 of spatial reasoning and the correlations related to hundreds of pupils of various levels of middle school (grade 6 to 9).

All in all, the results indicate weak correlation with school subjects. For example according to the tests, between .20 to .26 with the life sciences, from .01 to .28 with history/geography, i.e. as much as with drawing class. In fact the tests of numerical reasoning are best correlated with mathematics and the tests of verbal reasoning with the French essay. This probably shows the role of former training and not of a pure reasoning independent of the contents. Indeed, a more detailed examination confirms this. Certain correlations show the importance of specificity for mathematics: the correlations with the four tests of numerical reasoning are the following ones: “Operations to supplement” .51, “Numerical Series”, .42, “Operations” .63 and “Algebra” .45. Two items from the best correlated test (Operations) are these: “How much do you add to the numerator of the fraction 5/24 to make it equal to 1/3” or “Which is the odd number whose triple lies between the square of 4 and the square of 5”. Obviously, more knowledge in mathematics is required than simply “pure” reasoning. In the same way, some of the tests of verbal reasoning are related to former knowledge (proverbs, analogies).

One could suppose that reasoning is more important in the older classes. But another study, Aubret (1987) concerning a thousand of pupils of grade 9 from 48 classes of 16 middle schools, using the tests of N'Guyen Xuan and others (in particular a test by Spearman) shows equivalent results. A pupil's future in the school system is expressed on a five point scale: those who leave school after grade 9 are graded “1”; those who continue on to obtain the “Baccalaureat»(the final exam in the French middle school system) are graded “5”. Tests of reasoning only modestly predict (.30 to .41) the future after the grade 9, whereas grades obtained in school at the end of the grade 9, predict with a correlation of .60.

Vocabulary and Encyclopedic Memory

Another assumption is that scholastic performance could be related to the long-term memory of the school knowledge vocabulary.

Vocabulary

The idea is not new and goes along with the empirical discovery of the importance of vocabulary in cognitive development. From the beginning of experimental psychology, vocabulary was a very important component of the composite tests of Binet and Terman (cf. the subtests of vocabulary in the Wechsler tests) and was even the subject of certain specific tests (Mill Hill, Peabody test, Binois-Pichot). This showed up in an old and forgotten study by Pichot and Rennes 1949. They correlated average grades in French, Maths, Science, History, and Geography for 263 pupils in 6th grade with the results of a Binois-Pichot vocabulary test, obtaining a correlation of .57. A correlation between those same grades with a test of reasoning (Matrices of Raven) resulted in only .15.

Vocabulary still remains a very important field of research with highly varied prospects. Some studies make inventories, an already extremely complex feat, like those of Nagy & Anderson (1984). Regarding to French vocabulary, several inventories have been made (Lété, 2004; Lété, Sprenger-Charolles & Colé, 2004) but only two of them are known to use their inventories to estimate the number of words memorized at school . These two studies come to the same estimates. Ehrlich, Bramaud du Boucheron and Florin (1993) start from a preselection of 2 700 words (adapted from a word dictionary, sorted by students) and come to an estimate of 9 000 known words at the end of French elementary school (grade 5; 10 years old). Déro has carried out a computerized counting from elementary school handbooks and has estimated, with an MCQ test, the acquired vocabulary for each school grade. He also came to about 9 000 words memorized at the end of grade 5 (Déro, Fenouillet & Lieury, submitted).

However, the majority of researchers seems more interested in learning mechanisms, in particular in young children (Hepburn, 2010; Marulis & Neuman, 2010), but also in specialized vocabularies like those of mathematics (Brown, 2008). Others again are interested in other school or cognitive performances, reading in particular, or comprehension of stories (Verhoeven, 2011; Lee, 2011). Many researches focus on the acquisition mechanisms of new words. To that purpose, a frequent hypothesis made is that both the phonological

memory and the repetition are strongly implied (Camba & Morra, 2009; Rosenthal & Ehri, 2011). However several researches also show the importance of vocabulary knowledge, interpreting that new words memorization is all the more easy that the phonological units have already been memorized (Camba & Morra, 2009). Thus, in a sample of 40 Greek children studying English at school, the learning speed of new English words was strongly influenced by their long term English vocabulary, but was independent of the phonological short term memory (Masoura & Gathercole, 2005). In the same way, the 9/10-year-old children's interpretation of new words did not seem to depend on the short-term memory span, but on the working memory and vocabulary knowledge (Cain, Oakhill & Lemmon, 2004).

Encyclopedic memory

The concept of Vocabulary is generally used as a whole (without subject's distinction), this is probably due to the fact that the majority of studies concern young pupils (elementary school). On the contrary, starting from middle school (French college, grades 6 to 9), the learning refers to subjects of a great specificity, History, Geography, Maths, Physics, Literature, Foreign Languages,…. This specific knowledge probably depends mainly on lexical and semantic memory. But by their specificity, their link to numbers (Maths, Physics and Chemistry, History, Geography), faces (History), spatial maps (Geography) or diagrams (Life and Earth sciences), our assumption is that encyclopedic memory is perhaps based on psychologically and neurologically specific mechanisms. Thus, many words are proper names "Julius Caesar, Manhattan, Shangaï, Uranus", or concepts which have meanings different from their equivalents in everyday life :for example the lexical unit "disc", which evokes a music CD, while solar disk in History, or "disc" in the mathematical sense, have different meanings.

To refer to the specialized vocabulary of these disciplines, we have proposed the concept of "Encyclopedic Memory" (Lieury, Van Acker, Clevede, & Durand, 1995a; Lieury, Van Acker, & Durand, 1995b) in reference to the "Encyclopédistes", the 18th century scientists Diderot

and d'Alembert. The encyclopedic memory thus represents the whole of the knowledge, words, categories, images, which are the stored base of our knowledge in long term memory. For greater simplicity and homogeneity, we concentrated on vocabulary to the exclusion of other knowledge, numbers, formulas, faces or maps, which could be subjects of later research.

Few studies have been done on these long-term memories for school knowledge and they often focused on university students. "The forgetting of Spanish" was studied by Bahrick (1984) over a period of 50 years. He discovered a rapid decrease of the vocabulary knowledge during the first year and a certain stability during the following years. He thus came to the conclusion that a stable amount of knowledge called "permastore" exists. In a review, Conway, Cohen and Stanhope (1992) show a comparable pattern regarding mathematics, sciences…where a rapid decline is noticed during the first years (1-6 years) to attain a stable retention (over 30 years). They proved the inaccuracy of the belief that knowledge acquired at school is rapidly forgotten. This conclusion was recently confirmed by Custers (2011) regarding scientific knowledge. Custers has studied the basic science knowledge (Physics, Chemistry, Biology) for medical students and doctors up to 25 years of practice. One of his interesting results was that, contrary to the popular thinking, the vocabulary was not that much forgotten during the two years which followed the studies. It was then subjected to a fast decline to reach a stability of 25/30% after two years of practice. The importance of scientific knowledge is also noticed through a multimedia learning situation about tectonic plates. The high prior knowledge learners take better advantage of the instructional explanations whereas the low prior knowledge learners need further explanations about their mistakes (Acuña, Rodicio & Sánchez, 2011). Knowledge importance is not systematically spotted by an increase of performance but can be by a strategy variability. Indeed Guo and Pang (2011) have shown that a partial learning strategy for geometry (notion) is more efficient for the grade 4 pupils who have no geometry notions than for grade 6 pupils, for who simultaneous multiple figures presentation were sufficient.

Varied and extensive knowledge should thus be of a great importance to determine cognitive performances. But what is the long term memory

capacity of this knowledge?

A synthesis of several of Lieury's researches on middle school pupils (unpublished (grade 6) or only published in French is presented hereunder.

Inventory of the vocabulary specific to school disciplines from grade 6 to grade 9

Even though there is an introduction to history and sciences in elementary school, the early years of French middle school (grades 6 to 9) are characterized by the massive appearance of specialized subjects, History, Mathematics, Biology, etc. Although knowledge is not limited to words but also depends on images (e.g. volcano, pyramid), faces (bust of Cleopatra, Louis XIV…), procedures (rules of syntax, rules of algebra…). For instance, Kyttälä et Lehto (2008) have shown connections between the working memory's spatial components and performances in different mathematics tasks. Nevertheless it was more achievable to make an inventory of words only. The inventory of words became (in particular in grade 8 and grade 9) sufficiently gigantic to justify this choice. Moreover, it is possible that words represent the majority of knowledge. Thus, it has been demonstrated that memory of images depends on denomination (Dual coding theory; Paivio & Csapo, 1969; Lieury & Calvez, 1986). In the same way, Kidd and Kirjavainen (2011), have shown that, contrary to a likely hypothesis, the acquisition of past tense morphology in Finnish does not imply the procedural memory but only the declarative memory for children aged 4 to 7.

A longitudinal study listing encyclopedic vocabulary over the four years was thus undertaken (Lieury et al., 1992; Lieury et al., 1995a and b; Lieury, 1996) in the largest college (8 classes in each of the four levels) in Rennes, France. Having failed to deal with the heterogeneous teachers' courses, the inventory was made using the college's textbooks. Those classes not having textbooks (technology, music), were not taken into account. As the inventory was to be specific to "encyclopedic" fields, usual vocabulary was excluded. Not having at that time a relevant database, the encyclopedic vocabulary was selected subjectively by various judges with reference to an inventory of the elementary school

vocabulary (Dottrens & Massarenti, 1963). Thorough research on elementary school vocabulary (Ehrlich et al., 1978; Déro et al., submitted) showed higher estimates: 9000 words at the end of Primary education (grade 5). The "fundamental" vocabulary of Dottrens and Massarenti thus probably corresponds to the very frequent words. It should be noted that one of major difficulties of such inventories is their sheer size (Nagy & Anderson, 1984), which often obliges researchers to work only on samples. We opted to work on the total corpus of textbooks, accepting a certain amount of subjectivity of the judges (student or professors) to remove the usual vocabulary.

Inventories are always complex operations, hence the dissensions between authors (Nagy & Anderson, 1984; Nagy & Hermann, 1987). Indeed, words differ not only by their graphic components and their grammatical alternatives (e.g. conjugated verbs) but also by their meaning (semantic memory). Thus, the word "disc" has different French meanings (CD), in sport (throwing the discus), in history (solar disk), in mathematics (full circle), in everyday life (parking disc); the lexical item "disc" thus refers at least to five different concepts. Rules of inventory were made respecting the general principle of dissociating all different semantic units. Thus we kept the same lexeme in various fields when it corresponded to different meanings, as in the example of disc. In the same way, plurals were differentiated when they referred to different concepts, as in "glass" and "glasses" (astronomical). On the other hand, when several grammatical forms, for example, combined forms of a verb, corresponded to the same meaning, only one word was counted. Naturally, in many cases, it is sometimes difficult to decide (e.g. to live and living). The rule was then to refer to several judges and to retain several units if they were considered semantically different.

The second rule is that of specificity. Generally, in the event of redundancy, a word is retained in the more specific field of reference; for example if "Cleopatra" is listed in both History and French, the word is only kept in the inventory of the most specific field, in this case, History. However, when a word (or proper name) appears only once in a nonspecific matter for example "Marie-Antoinette" (wife of Louis XVI) in French vocabulary in 3rd (grade 9), it was preserved.

The third rule was to make inventories of the school levels without repeating words from the previous years. For example, "Ramses,

Pyramid, …" were not added to the vocabulary of grade 7. A comparison of the vocabularies of grade 6 and grade 7 (Lieury et al., 1992) showed only weak overlap, 13% on average, from 5% in history (where the programs are very different) to 34% in foreign language (English).

Table 2
Inventory of vocabulary in textbooks of 4 levels of collège according to subjects (except usual vocabulary).

		Grades			
		6	7	8	9
School subjects	French	1 989	2 692	5 379	7 049
	History	1 088	2 841	3 257	6.722
	Geography	824	1 370	2 636	**
	Civics	872	421	1 646	2 917
	Biology (Geology in grade 8)	402	776	1 099	2 456
	Foreign language *	716	1 164	2 354	2 272
	Physics and chemistry	259	212	1 131	2 133
	Maths	167	203	571	440
	Total	6 317	9 679	18 073	23 989

* English being chosen by 90% of pupils, total includes only vocabulary of this foreign language; the second foreign language from grade 8 was not inventoried.
** In the grade 9 program level, history and geography being very close, a common inventory was carried out.

The inventories (see Table 2) show a considerable increase in the number of words in obligatory textbooks, from approximately 6 000 on the first level of "collège" up to 24 000; this confirms the "ocean of words" expression of Nagy and Hermann (1987) with which pupils are confronted. The analysis by subject reveals, moreover, considerable

disparities between them, indicating indirectly that declarative memory is probably not solicited with the same importance, in particular in mathematics (which is the most dependent on reasoning or procedural memory).

Estimate of Encyclopedic Memory in Pupils

MCQ of Encyclopedic Memory

The estimate of encyclopedic storage capacity was deduced from responses on a MCQ. This was primarily aimed at testing the semantics of the words. For this purpose, a sample of one hundred words, for each of the height domains, was selected by quota (words arranged alphabetically); so there is a total of 800 items per school level.

The method of the MCQ (derived from the technique of recognition in memory, with the choice between a target and one or more lures) was to surround the target (i.e. the right semantic answer) with two lures; the last choice being "I do not know" so as not to force pupils to make errors. In order to allow short items, the test is to surround the answer "closest" (the target) to the test item. Examples are given before the test to show some types of right answers and lures: the "closest" answer is a translation in Languages, a synonym in French, but the country for a city or a river in Geography or History. Here some examples of items for each subject (see Table 3).

Table 3
Examples of questions for each of the eight subjects in the MCQ of grade 8: the questionnaire comprises hundred questions by subject (800 on the whole) (adapted from MCQ in French for this publication).

HISTORY	GEOGRAPHY	CIVIC EDUCATION
Marie-Antoinette	Cuba	ONU
1 - Wife of Louis XVI 2 - Sister of Louis XIV 3 - Mistress of Louis XV 4 - I don't know	1 - Island close to America 2 - Island of Pacific 3 - Island close to Africa 4 - I don't know	1 - For health 2 - For Peace 3 - For Europe 4 - I don't know

Table 3
Examples of questions for each of the eight subjects in the MCQ of grade 8: the questionnaire comprises hundred questions by subject (800 on the whole) (adapted from MCQ in French for this publication).

GEOLOGY-BIOLOGY	**PHYSICS-CHEMISTRY**	**MATHS**
Pyroxène	Uranus	Vector
1 - Weeding 2 - Glass resisting 3 - Mineral of basalt 4 - I don't know	1 - Meteorite 2 - Galaxy 3 - Planet 4 - I don't know	1 - Point 2 - Oriented line 3 - Non oriented line 4 - I don't know
FRENCH	**ENGLISH***	**DEUTCH***
Ire	Pepper	Sanft
1 - Anger 2 - Song of bird 3 - Guru 4 - I don't know	1 - Poivre 2 - Menthe 3 - Epuisette 4 - I don't know	1 - Without 2 - Soap 3 - Soft 4 - I don't know

*Pupils fills one MCQ of language corresponding to their 1st foreign language.

Although the structure of MCQ is especially oriented to test semantic storage, we have used the technique of placing lexical lures (phonological or orthographical), to test possible confusions with similar words. For example "courroux" ("anger" in French") is used as a lure (see Table 3) for pupils for whom this word would wrongly evoke "gourou"("guru"); in the same way the lure "Australia" for "Austral" ("southern") etc.

Each year, experimentation proceeded as late as possible in the school year (the last week or last two weeks of June) to allow for maximum acquisition of concepts. The place was the "Hautes Ourmes" middle school in Rennes (France). The testing was collective, monitored by several professors and students. The testing took two mornings at the rate of four MCQ per morning with breaks; time was free within the limits of the morning, the fastest pupils could go out after completing two tests. Invigilators (teachers and students) and experimenters were available to pupils who had problems understanding some items. On the whole, MCQ were appreciated by the pupils, some of whom asking

whether the experiment would continue the following year. The pupils were informed that the test did not count for examinations but was part of a study on the difficulty of school textbooks.

Estimate of the Encyclopedic Memory of Pupils

Compared to the psychometric method (selection of the discriminative items), the main aim of the experiment was to evaluate encyclopedic storage capacity of pupils, viewed as the capacity of long term memory. This is why the items of MCQ were randomly selected, 100 items per subject. The estimate of vocabulary known at the end of the year by a pupil is made by applying the percentage of successes to the totality of words inventoried in one subject. For example, the inventory of words in History in grade 6 numbering 1088, a pupil who has 40% success is regarded as having acquired 435 words. A total is then made for the eight subjects.

This estimate gives in grade 6 (N = 190) approximately 2500 words acquired on average at the end of year, approximately 5000 words at the end of grade 7 (N = 212; Lieury et al., 1995a and b), approximately 11500 in grade 8 (N = 147, Lieury, 1995a) and approximately 17000 (N = 174 pupils) in end of grade 9 (Lieury et al., 1995b). The rate of acquisition would thus not be linear but would approximately double each year for this school period (see Figure 1).

Moreover, there are enormous disparities in pupils' long-term storage capacities, in terms of thousands of words; for example the lowest estimate at the end of grade 6 is of 1000 words stored by some pupils against 4000 for pupils having the best estimate. And in grade 9 (on the same cohort, but without those pupils who have repeated the year), the variations go from 10 384 words to 20 562 for the best estimate; this difference is about ten thousand words, which is enormous compared to differences in scores on tests of short-term memory, or declarative memory in laboratory conditions.

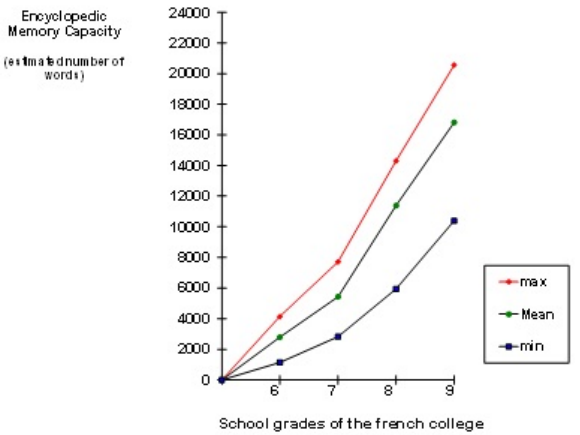

Figure 1. Estimate of encyclopedic storage capacity measured by number of words acquired at the end of year, from grade 6 to grade 9 of middle school.
The average relates to eight classes on each level, minimum and maximum correspond to least (min) and to best (max) scores.

Encyclopedic Memory and Academic Achievement

Correlations between encyclopedic memory and school results

The implication of encyclopedic storage capacity in school performances was measured by the correlations between various scores of MCQ and annual averages, by subject or general average grades. These results were published but only in French (Lieury et al., 1992; Lieury et al., 1995, a and b) so a selection of results is given in this synthesis article.

Generally, the corrected score, "Successes minus Errors" (S-E), gives better correlations than a simple score of success, which does not take into account errors (in particular errors on lexical lures). At grades 8 and 9, we considered that a score "Successes-Errors/2 decreasing the score of successes only by half of the score of errors, was more logical since

there were always two lures per target. Practically, correlations between S-E and S-E/2 were very similar.

Table 4
Correlations between total score (S-E or S-E/2) with encyclopedic MCQ of memory and annual school average (Lieury, 1991; Lieury et al., 1992; Lieury et al., 1995a, 1995b) in function of grade.

	grade	MCQ	n
Average school grades	6	.69	190
	7	.72	138
	8	.69	147
	9	.61	174
	Brevet *	.64	174

* "Brevet" is a national final examination after 4 years of college (grade 9) including three tests (Maths, French and History-Geography).

Calculation of correlations was in general carried out with average of annual grades in subjects which we called "specific", i.e. corresponding to those in which we made inventories. All in all, correlations (S-E in grade 6 and 7 or S-E/2 in grades 8 and 9) are high, between .60 and .70 with annual average of school grades (see Table 4). The correlations appear higher than those obtained with tests of reasoning (N'Guyen Xuan, 1969) and especially higher than those with tests of short-term or episodic memory (rote learning). In addition to these tests, grade 9 pupils were also tested with two working memory tests: a backward digit span and sequential memory test, (Larson & Saccuzzo, 1989). The correlations with academic achievements were moderate, for Backward span (.23) and sequential memory test (.40) and higher for encyclopedic memory test (.62) (Van Acker, Vrignaud & Lieury, 1997).

Encyclopedic Memory and Follow-Up after 4 Years

Although this research followed the same group of pupils, each study presented was done as a cross-sectional study because certain pupils, during our follow-up, repeated a year and others only entered the school after grade 6 (e.g. recent arrival). The fact of not taking account of repeating pupils in the longitudinal study leads to skewed correlations, since the weakest pupils are absent from the measurements. The totality of the cohort of grade 6 was thus analyzed to observe the implication of encyclopedic memory up to four years later. For that, pupils were classified in 8 levels according to their "school careers". Three levels are reserved for pupils who repeat a year (grades 6, 7 and 8); the levels 1 to 5 corresponds to five groups of grades according to their average on the final examination (grade 9 = "Brevet" in France). Note that this examination was corrected by teachers from outside the school. Each level represents a progression of 2,5 grade points (on a total of 20): level 1 <7.5/20; level 2 <10; level 3 <12,5; level 4 <15 and level 5 >15.

There were 162 pupils whose files were complete; of the pupils who began the experiment (in 1990), 28 left the school during the four-year experimentation. The results show the strong correlation of .71 between the scores of encyclopedic memory (S-E/2 on MCQ in end of grade 6 and scholastic success (see Table 5). Note, however, that the best predictor of school evolution is still the general average of all grades, with a correlation of 0.84.

Table 5
Correlations between grade average and encyclopedic memory at grade 6 and school "career" 4 years later (grade 9), (N = 162).

	Grade average in grade 6	School « career » 4 years later
Encyclopedic memory (MCQ in grade 6)	.71	.71
Grade average in grade 6		.84

It is noticed that the encyclopedic score of memory is surprisingly predictive, being of .712 with the school average of grade 6, and is still of .714 with scores obtained four years later. This result is very important because it shows that an encyclopedic questionnaire of memory has a very important degree of generalization beyond the program from which words are extracted. The results from the questionnaire could be thought to be well correlated with results of the same year, because in fact partly the same words are in the questionnaires and the interrogations. However, the extent of one year's knowledge is very predictive. Reasons are probably multiple. The extent of vocabulary probably measures the capacity of long-term memories, seen as the "hard drive" of human memory, but also the capacities of abstraction which allow us to differentiate between similar concepts, like divider and dividend, king and pharaoh, etc. Moreover, if inference from context is a major mechanism in learning new words (Nagy & Anderson, 1984; Sternberg, 1987), the more words a learner knows, the greater his capacity to make inferences about a new word. Thus, on the eight classes of the cohort, it is always the same two pupils who have the best scores of encyclopedic vocabulary (Lieury et al., 1995b) throughout the four years, and who have the best performances on the final examination in grade. Also let us note that reliability of school grades is very good.

As we have mentioned, a correlational study over several years can be skewed by the pupils who repeat a year (Lieury, 1996). In our test group, 51 pupils repeated a year, 22 in grade 6, 23 in grade 7 and 6 in grade 8, i.e. 31% of the participants. Thus, if we remove these "repeat" pupils, correlation between encyclopedic MCQ in grade 6 and the average grades on the final examination drops to .58 (instead of .71). According to our estimates on the basis of success on the multiple-choice questionnaire (random sampling of all words, by subject), the pupils who repeated a year had a score of encyclopedic memory lower or equal to 2500 words in end of grade 6: 2195 for repeating their year in grade 6, 2491 for the pupils who repeated the grade 7 and 2070 for those who repeated the grade 8. The pupils having the best scores (average point higher than 15/20) had a capacity of 3500 words out of approximately 6000 words inventoried in the textbooks at the end of 6th.

Discussion and Conclusion

If memory is generally important, traditional laboratory tests (Recall, Recognition…) sensitive to aging, have little or no correlation to school or university achievement. On the contrary, what is crucial is long-term acquisition of encyclopedic knowledge, called "encyclopedic memory". In the follow-up of a cohort of approximately 200 pupils of French collège from the grade 6 (11 years) to the grade 9 (14 years), encyclopedic memory score is surprisingly predictive. At .712 with the school average of grade 6, it is still at .714 with scores obtained up to four years later. This result shows that an encyclopedic memory questionnaire has a high degree of generalization beyond the program from which the words are extracted. The mechanisms are probably multiple. Extent of the vocabulary probably measures the capacity of long-term memory, seen as the "hard drive" capacity of human memory; but also the capacities of abstraction which make it possible to differentiate between related concepts, like "divider" and "dividend", or "king" and "pharaoh", etc. Moreover, if inference from context is a major mechanism in learning new words (Nagy & Anderson, 1984; Sternberg, 1987), the more words are known, the greater will be the ability to understand a new word. Thus, out of the eight classes of the cohort, it is the same two pupils who have the best scores of encyclopedic vocabulary (Lieury et al., 1995b) during the four years and who have the best performances on the national evaluation in grade 9.

Is the "encyclopedic memory" term useful? It has principally been used to distinguish the specific teaching knowledges in middle school; History, Geography, Mathematics, Physics, Literature, Foreign Languages … This specific knowledge probably mainly depends on the lexical and semantic memory. But by the specificity of this vocabulary; its link to numbers (Maths, Physics and Chemistry, History, Geography), faces (History), spatial maps (Geography) or diagrams (Life and Earth sciences), the hypothesis presented here is that encyclopedic memory might be based on psychological and neurological specific mechanisms that can be different from the common vocabulary ones. The authors 'abilities are not sufficient enough to make a neurological researches synthesis in this discussion. However, it seems interesting to point out some researches which

appear to show possible specific neurological mechanisms. The specificity is being detected at the cortical level, for example for numbers (in particular the parietal cortex, Dehaene, 2003) or for faces, which activate the spindle-shaped gyrus more intensely than do manufactured objects (Joseph & Gathers, 2002). Moreover, recent research shows one specialization during the child's development: ventral recognition of faces and objects in all children from 5 to 11 years, while in adults and children of 9 to 11, faces activate more specifically the spindle-shaped gyrus (Gathers, Bhatt, Corbly, Farley & Joseph, 2004). Richardson, Thomas, Filippi, Harth and Price (2010) shows the implication of the left posterior supramarginal gyrus in the learning phase (in teenagers) while the temporal cortex is activated, at all ages (teenagers or adults) for acquired vocabulary. In the acquisition of a foreign vocabulary through the use of semantic or pictorial procedures, Macedonia (2010) demonstrates an implication of the left angular gyrus as well as of the left extrastriate cortex.

As a conclusion it is interesting to note for future researches that this study concentrated on vocabulary to the exclusion of other knowledges, numbers, formulas, faces or maps. The mechanism of “dual coding” (Paivio & Csapo, 1969; Lieury & Calvez, 1986) which holds that pictures are coded verbally as well as in image code, would contribute an additional reason for the efficiency of vocabulary. In the same way (Lorant & Lieury, unpublished) in a study on the maps used in Geography, the names of cities were more crucial than their spatial placement in the learning of a map. And Kidd and Kirjavainen (2011) have shown that past tense morphology acquisition in Finnish does not involve procedural memory but only the declarative memory. However, the vocabulary does not cover the whole knowledge, the faces of famous historical people (Julius Caesar, Nefertiti), the continents and country shapes, the mathematical formulas and the chemistry symbols also play a role. This knowledge could be the subject of later research.

Notes

* Thanks to the translators Sharyn Thepot and Emeline Kenward.

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