What makes a number easy to remember?[1]

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Abstract

Natural categories (such as birds, furniture or pieces of music) include 'good' and 'poor' exemplars. While there are a number of factors that determine the extent to which an item is a good category member (prototypicality, distinctiveness, frequency of occurrence), a consistent experimental finding is that that 'good' category members are better remembered than 'poor' ones. Can numbers be considered a natural category of this sort, with good and poor members? This study tested memory for number lists, using numbers between

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1 and 100 in a list learning task in which both Recall and Recognition tests were given to over 500 subjects.

Stepwise regression on the memorability scores for each number between 1 and 100 indicated that four attributes made a significant contribution to the variance. ANOVA confirmed that these attributes had individually significant effects on memory for numbers. Recognition and Recall gave similar scores under these conditions.

The order of memorability was (1) Single digit numbers, (2) Teen numbers (10-19), (3) Doubled numbers (e.g. 44, 77, 22), (4) Large tabled numbers (numbers which factor and therefore appear in the multiplication tables, such as 49, 36, 60, 84, 27) and (5) Other numbers that do not fall into any of these categories.

While memorability for Single digit numbers was above 80 percent, that for Other numbers (no subcategory) was only around 40 percent.

What makes a number easy to remember?

The prime function of numbers, as a category, is the representation of magnitude. Each member denotes a different value. The category is ruled by a simple syntax. Once those rules are mastered there is no limit to the amount of numbers that can be correctly produced. Children will sometimes count for hours, or even days, after the fascinating system has first been revealed to them. Numbers are special. A person does not need much knowledge to list many, many numbers. In this respect other categories, such as birds, football players or psychological concepts, are much more difficult to learn.

Considering these formal properties, it is interesting that numbers are not all equally available for mental consideration. In many contexts small numbers come to mind more easily. This is well illustrated by the literature on simple arithmetic, which shows that number size is a good general predictor of problem difficulty. This is even so for adults, who may be presumed to know the basic 'number facts' by heart. The semantic advantage of small numbers is also illustrated by the choices people make when asked 'to name just a number' (Dietz, 1933), or to produce an association to a given number

(Milikowski & Elshout, 1994). These authors, using all numbers from 1 -100 as stimuli , found that small numbers made up a very large part of the response set. Indeed, half of all responses obtained in a setting of continued association consisted of numbers under twenty. An even stronger bias toward small number responses was found in an other experiment (Milikowski & Elshout 1992). This time, subjects were invited to make up their private categories, listing favourite numbers, hated numbers, interesting numbers, uninteresting etc. Of all 7681 responses obtained, over eighty percent were numbers under twenty. Small numbers, it would seem, are easily accessible, and can be made to fit a variety of prescriptions.

Even judgments about formal attributes of numbers can be affected by this mental gradient. This is evidenced by a study of Armstrong et al (1983), who had subjects rate concepts for 'typicality'. Two of the categories these authors used were even and odd numbers. An inspection of the tables presented confirms that typicality as measured in this experiment is inversely related to size. Thus, 2 was rated as more 'typicality even' than 34, and 3 as more 'typically odd' than 501. (Armstrong et al, 1983, p. 276).

Interestingly, small numbers are also felt to take more individual space. This was discovered by Banks & Hill (1974), who reported that people's self constructed number lines are implicitly compressive, the experienced distance between numbers decreasing as a function of their objective magnitude. Such examples suggest that the category of numbers, though special in its formal properties, has a mental structure similar to other semantic categories.

A semantic category is a collection of items belonging to the same class of things. Frequently used examples are concrete objects such musical instruments, vehicles and pieces of furniture, but in fact many domains of knowledge may be brought under this heading. There is a wide literature on semantic categories, to which findings about numbers may be compared. An important aspect of semantic categories is their graded structure. This means that, within a category, concepts have a different degree of mental prominence. This was first discovered by Eleanor Rosch, who found that subjects could consistently rate concepts on a scale of 'typicality' (Rosch, 1973, 1975, 1978). For example, a car was felt to be a more 'typical' vehicle than an airplane, and a dog a more typical animal than a sheep. Gradedness is a dimension specific to psychological knowledge structures. From a viewpoint of external knowledge organisation, dogs and sheep are animals to the same degree, both belonging to that class by definition. This may well be recognized by people who, nonetheless, experience a difference when consulting their own minds. The experienced difference may in fact have a more general cause and be related to such factors as availability, inmageability or meaningfulness of a representation. It might then be interpreted in more specific terms if these are suggested by the situation. In this study we will use the term 'prominence' to denote the general phenomenon.

The relative prominence of concepts within most semantic categories is correlated with the frequency of their use in general language (Armstrong et al 1983, Nebes 1989). This seems to be the case for numbers also. In a recent study Dehaene & Mehler (1992) compared the frequencies of Arabic numbers and number words in six languages. In each of these, frequency was inversely related to size. Another finding is that when people must name exemplars of a category, the more prominent members are generally named first (Rosch 1978, Nebes 1989). This may be compared with the consistent favouring of small over large numbers in the experiments mentioned above (Dietz, 1933; Milikowski & Elshout, 1992, 1994). Moreover, more prominent concepts will be recognized and named more quickly (Rosch 1975; Armstrong et al 1983, Smith et al 1974). Similar effects have been found in experiments with simple addition and multiplication problems, where small number problems are associated with shorter RTs. (See Ashcraft, 1992, for a recent review). As a final point, it has been established that more prominent concepts within a semantic category will be better remembered when they appear in some list (Hasselhorn,1992, Saarnio 1992, Harnishfeger & Bjorklund 1990, Cisse & Heth 1989). The influence of semantic variables on the memory for numbers has not yet been investigated. This was the purpose of the present study.

In the next section, an experiment will be described in which subjects memorised and reproduced numbers. Our interest was in isolating those properties of numbers which, over time, have led them to be more strongly represented and thus easier to remember. All numbers from 1 to 100 were used. Because numbers have many attributes which may influence their semantic strength and their distinctiveness as a stimulus, we first determined in a stepwise regression analysis which variables made a significant contribution. On that basis numbers were divided into five non-overlapping subcategories, which could be compared in ANOVA.

Method

Materials. All numbers 1 through 100 were used as stimuli. Five lists were composed, of twenty numbers each, presented as Arabic numerals. (See Appendix 1). Three rules were followed: small numbers and tens had to be distributed evenly; no more than three numbers from a decade could appear in the same list, and lists should be balanced as to the proportion of odd and even numbers. Each list was then ordered so that obvious clusters were avoided. Of the five lists, three versions were composed, to control for differences in the serial position of numbers. The position of the numbers was varied by dividing each list into parts a, b, and c, consisting of 7, 6, and 7 numbers respectively, and making the following combinations: abc, bca, and cab. Lists were printed in one column on sheets of A4 paper.

As testing was to take place in two conditions, two versions of the response sheets were prepared. For the Recall condition, a response-sheet of paper with twenty open lines was printed. For the Recognition condition, all hundred numbers were printed on the response-sheet in order of magnitude.

Subjects. A total number of 597 undergraduate students were tested collectively, in two separate sessions. Of these, 289 subjects participated in the Recall condition and 308 in the Recognition condition.

Procedure. The numbers-test was part of a large battery of tests and questionnaires. Five experimenters were present to assist. Subjects sat behind desks, as in an exam. They were advised to follow the printed instruction carefully, which were read out by one of the experimenters. The instructions informed subjects they would be given 90 seconds to study the numbers printed at the back of their sheet, and that they would be tested later. Subjects were not allowed to write anything down. The experimenters kept time with a stop-watch. After 90 seconds, subjects were instructed to put the numbers sheet into a folder together with other completed tests. The interval between studying time and testing time was over an hour in both conditions. During this interval, six questionnaires on various subjects were completed, and a short rest was taken. Subjects were then given 90 seconds to fill out their response sheet. In the Recall condition, this meant writing down numbers on twenty blank lines. In the Recognition condition, it meant marking the target numbers in the presented hundred numbers. In both conditions, guessing was discouraged by the announcement that incorrect responses would be subtracted from their scores.

Variables Seven attributes of numbers were selected for participation in a stepwise regression analysis. Some are related to size and some are not.

1. Magnitude. Standing for the numbers' actual value and varying from 1 to 100.

2. Syllables. Standing for the number of syllables in the number-word. (Number of syllables varies between 1 and 6 in Dutch).

3. Even / odd. A dichotomous variable, distinguishing between 50 even and 50 odd numbers.

4. Singles. A dichotomous variable, distinguishing between the single digit numbers (n = 9) and all others.

5. Doubles. A dichotomous variable, distinguishing between 11, 22, 33, 44, 55, 66, 77, 88, 99 (n = 9) and all others

6. Teens. A dichotomous variable, distinguishing between 10-19 (n = 10) and all others

7. Tabled. A dichotomous variable, distinguishing between the numbers used in the multiplication tables 1-12 (n = 53) and all others. This category overlaps with some of the other categories. In addition to the numbers 1-12, the tabled numbers are 14, 15, 16, 18, 20, 21, 22, 24, 25, 27, 28, 30, 32, 33, 35, 36, 40, 42, 44, 45, 48, 49, 50, 54, 55, 56, 60, 63, 64, 66, 70, 72, 77, 80, 81, 84, 88, 90, 96, 99, 100.

Data treatment For each number two individual scores were determined. These scores consisted of 1) the proportion of subjects assigned to the relevant list that had correctly recalled the number and 2) the proportion of subjects assigned to the relevant list that had correctly recognized the number. Each number was also scored for its appearance as an intrusion. These latter scores had were required to ensure that the differences we hoped to find were real, and not caused by some numbers' irresistible intrusiveness. For subjects absolute Recall and Recognition scores were also determined and pooled over list-groups to check for list-effects.

Results

General In both conditions six answering sheets were judged to be invalid, in eleven cases because it could not be determined which list had been studied, in the twelfth case because the response-sheet said "I have cheated in this test". A total of 585 answering sheets remained (283 Recall and 302 Recognition). Distribution of the five different lists of numbers had not been completely equal, but the differences were not significant statistically, X^2 (4, 580) = 3, p = .45.

Lists Subjects assigned to different lists did not perform significantly different in either respect: F(4, 580) = 37.8, p = .83 for correct scores; F (4, 580) = 1.61, p =.17 for intrusions. All lists were equally difficult to remember.

Numbers

Stepwise regression A stepwise regression analysis (F to enter = 4) revealed that of the seven variables that were introduced (see methods section), four made a significant contribution to the explanation of numbers' scores. This was the case both for Recall scores and for Recognition scores. These four variables are, in order of magnitude: 1. Singles, 2. Teens, 3. Doubles, 4. Tabled. The multiple correlation of those variables with retention scores was quite high in both conditions. For Recall an R of .81 was obtained, F (4, 95) = 45.98. For Recognition the obtained R is .77, F (4, 95) = 35.47 Both analyses were performed in six steps, with identical patterns for Recall and Recognition. Magnitude was the first variable selected, its correlation with retention scores of numbers being .58 and .57 respectively. Magnitude was removed again as a fourth step, after Singles and Teens had been selected. After extraction of the four variables mentioned, Magnitude was left with Fs to Enter of 1.27 for Recall and 2.57 for Recognition. The contributions of Evenness and Syllables were not significant at any moment in the procedure.

Categories Because we were interested in a comparison of means, the variables found to be significant were used to divide all numbers into five distinct (non overlapping) categories. A full specification is given in Appendix 2. The category structure is built up by a stepwise removal of overlaps. Thus, the first category is singles (nrs 1-9). The second is Teens (nrs 10-19). The third is Doubles (starting with 22). The fourth is Large Tabled, being the tabled numbers (see methods section) minus the singles, the teens and the doubles, leaving 29 numbers. The last category is Others, consisting of all numbers that do not belong to any of the categories mentioned.

Category	% recalled		% recognised		% overall	
Singles (n = 9)	82	(7)	84	(11)	83	(9)
Teens (n = 10)	72	(9)	72	(9)	72	(6)
Doubles (n = 8)	59	(9)	66	(14)	62	(11)
Large Tabled(n = 29)	42	(14)	49	(14)	45	(13)
Other (n = 44)	34	(11)	38	(12)	36	(11)
Overall (n = 100)	47 %	(20)	51 %	(20)	49 %	(19)

Table 1 Mean percentages of correct reproduction of five categories of numbers, in two experimental conditions. Percentages are given in whole numbers.Standard deviations are given within brackets.

<u>Comparison of categories</u>

As could be expected, the overall difference between the category means is highly significant for both testing conditions, $F(4, 95) = 46.95$, $p < .0001$ for Recall, and $F(4, 95) = 38.94$, $p < .001$ for Recognition. There is also a highly significant effect of testing condition as revealed by a repeated measures Anova, $F(1, 95) = 48.88$, $p < .0001$. In the Recall condition, performance is worse than in the Recognition condition, mean percentages correct retrieval being 47 and 51 respectively. No interaction was found between numbers categories and testing condition, $F(4, 95) = 1.41$, $p = .24$.

A post hoc comparison revealed that for Recall-scores, the comparison between Singles and Teens is not significant. For Recognition-scores, the comparison of Teens and Doubles is not significant. All other comparison are significant at an alpha level of .05.

Table 1 presents the category means obtained in both conditions. The Table shows that Single digit numbers are most easy to remember, being correctly reproduced in 82 percent of all cases in the Recall condition, and in 84 percent of the cases in the Recognition condition. Next come Teens, with a percentage correct reproduction of 72, in both conditions. Doubles are third, with percentages of 59 and 66, followed by the category of Large Tabled numbers, with percentages of 42 and 49. The numbers that do not belong to any specific category are remembered worst, being correctly reproduced in only 34 and 38 percent of the cases.

Intrusions Subjects produced 2.01 (Recall) and 2.78 (Recognition) intrusions on the average. Larger numbers tend to appear somewhat more frequently as intrusions, R = .36, p < .001). The scores of best remembered categories (smaller numbers) do not appear to have been contaminated by mistaken represduction.

Easy numbers		Difficult numbers	
Recall	Recognition	Recall	Recognition
8	7	82	39
1	2	56	61
100	5	61	87
2	100	94	83
17	8	85	79
5	12	45	41
9	3	83	82
10	99	59	84
99	17	41	62
11	44	79	59

Table 2. Best and worst remembered numbers (named easy and difficult) in two conditions. For each condition, the ten highest and the ten lowest scoring numbers are presented, ordered by the magnitude of their scores. .

Discussion

The differences found in this experiment are quite large. Small numbers are remembered well. They have a chance of over eighty percent of being correctly recalled or recognized. In contrast, numbers belonging to no specific subcategory have a poor chance of being remembered, with average percentages of less than forty. Teens, Doubles and Tabled numbers take intermediate positions.

Magnitude has a strong influence. For the most part, this influence can be captured within a simpler structure of sub-categories of numbers. These sub-categories organize numbers largely on the basis of their magnitude. The prime distinction in this respect is between Singles, Teens, and all other categories. However, even the subcategory of Large Tabled numbers, which in this comparison does not contain the tabled numbers under twenty and the doubles, is of a smaller average magnitude than the unspecified category called 'Others'. Mean magnitudes are 52 and 63 respectively. Moreover, scores within each subcategory have a negative correlation with magnitude. These correlations vary between -.18 for Tabled numbers and -.26 for Singles. None of them are significant, but all are in the expected direction.

A special case are the Doubles, which is the only high scoring subcategory with a mean magnitude value (60) that is higher than that of the whole set (50). The advantage of the doubles may have been partly superficial, standing out as they do, by the repetition of two digits. Singles, equally, may well have obtained some extra profit from their visual distinctiveness.

Though the influence of magnitude is large and pervasive, it seems to be indirect rather than direct. By this we mean that is not to be explained by the specific contents of a number's representation, but by the presence or absence of any content . The problem with some larger numbers is not that their representation is so large, but that it is insufficiently specified. It does not contain the information needed for correct identification. For that reason, they are sometimes confused with other numbers that are equally underspecified, and may share some of their characteristics.

It is quite illuminating to compare the ten best remembered numbers in both conditions with those scoring worst. These numbers are printed in Table 2. As can be seen, all well remembered numbers are either Singles, Teens or Doubles, with the exception of 100, which is the sole representative of the Large Tabled numbers. Most of the lowest scoring numbers, in contrast, belong to the the nameless category of Other numbers.

People don't like such numbers. At one point in our research we had subjects rate all numbers 1-100 on a series of scales. Some of these findings are pertinent to the present discussion. One scale we used was a good-bad scale. This scale proved to be quite reliable, giving an alpha of .81 for all numbers, and one of .91 for a selection consisting of the twelve top and the twelve bottom numbers. It is interesting to compare this selection, which is given in Table 3, with the ratings obtained in the present experiment. The twelve 'good' numbers are, in order of the magnitude of their goodness ratings: 10, 100, 36, 8, 24, 66, 16, 4, 1, 88, 21, 12. As can be seen, they all belong to one of the privileged categories. The twelve 'bad' numbers are, in the same order: 37, 93, 41, 51, 39, 17, 13, 59, 29, 43, 53, 67. Interestingly, all belong to the 'Other' category of numbers that is also difficult to remember. In a small follow up experiment , we had 21 subjects memorise the lists of 'good' and 'bad' numbers, which were presented to them in Arabic format, on a sheet of paper .These students were given a minute to study a list of twelve numbers, after which they had to reproduce it immediately. Ten subjects first memorised and reproduced the list of good numbers, and tackled the bad list after a short pause. Eleven subjects took the test in a reverse order. Of particular interest here is the nature of the intrusions that were produced. For the 'good' list , which was perfectly reproduced by fifteen out of twenty-one subjects, only one intrusion was obtained, being the number 64. Subjects had more problems with the 'bad' list, which was correctly reproduced by only one of them. Moreover, there were fifteen intrusions. We have listed them in Table 3, because they seem to shed some light on the kind of things people do remember about such 'bad' and difficult numbers.

'Good' list

Members	10, 100, 36, 8, 24, 66, 16, 4, 1, 88, 21, 12
Intrusions (n=1)	64

	'Bad' list
Members	37, 93, 41, 51, 39, 17, 13, 59, 29, 43, 53, 67
Intrusions (n=15)	63 (3 x), 19 (3 x), 69 (2 x), 83, 79, 57, 49, 33, 31, 23

Table 3. List of twelve 'good' and twelve 'bad' numbers, with the intrusions produced by subjects

As the table shows, all intrusions are odd numbers, consisting of two digits, the second of which is either 1, 3, 7, or 9. In these respects the intrusions are similar to the stimulus numbers.

Of equal interest in the context of this discussion is a comparison with the numbers' Meaningfulness, as determined in an association experiment (Milikowski & Elshout, 1994). Following Noble (1963), Meaningfulness was defined as number of associations produced during a fixed time, which in this case was thirty seconds. On the whole, Meaningfulness has no strong correlation with retention-scores (.45 and .42 for Recall and Recognition respectively). However, when we look at the extremes, it is evident that the categories found to distinguish numbers in the present experiment have some relevance for their Meaningfulness too. The ten numbers with the highest M-scores are, in descending order, 12, 50, 10, 60, 15, 16, 100, 11, 34, 22. With the exception of 34, these are all numbers belonging to one of the privileged categories. The ten numbers with the lowest M-scores are, in the same order, 74, 87, 78, 98, 43, 59, 68, 85, 76, 67. All these numbers belong to the 'Other' category of numbers that are so difficult to remember.

We will now return to the proposal in the Introduction, that the category of numbers is a semantic category, with more and less prominent members, which have more and less distinctive representations. Our results strongly suggest that numbers may be so viewed. Numbers display a mental hierarchy that seems to stand up well against changes in experimental context. Moreover, this hierarchy seems to be related to a fairly simple set of properties which numbers may or may not have.

From this, some things follow and some do not. To start with, we are open to the possiblity that the sub-categorisation used is this experiment may be replaced by some other. An alternative, which we have used in other experiments (see for instance Milikowski and Elshout, 1994) is to distinguish between Tabled and Non Tabled numbers only, Tabled numbers being defined as the numbers 1-12 and their products between 1 and 100. Such a sub-division would collectively contrast the Singles, the Teens minus 13, 17 and 19, the Doubles and the Larger Tabled numbers with a slightly extended category of Others, which would also contain 13, 17 and 19. Another possibility is divide the numbers into three categories consisting of one, two or three morphemes. This would contrast the numbers with the simplest morphemic structure in Dutch (1 - 10, or, alternatively, 1 - 12), with those consisting of two morphemes (the teens and the tens), which may again be contrasted with those consisting of three morphemes (all others). All such sub-divisions are defensible, and each will capture a good part of the variance in experiments such as the present one. The reason is that the numbers system itself discriminates between numbers. Some numbers participate in many substructures and some in few. 'Other' numbers, are not favoured by the numbers system. They have few intrinsic properties suitable for bringing them to peoples attention.

We are not suggesting that there is any specific basis for rank ordering numbers mentally. For one thing, experts will have permanent semantic information for distinguishing numbers which non-experts are bound to confuse. For another, variations of context and task demands, highlighting different features of numbers, will always produce some changes in the hierarchies obtained. This is only too obvious from our and others' experiments. What has been persistently argued by Barsalou, that representations of concepts do not lie in wait to be accessed, but are constructed tot fit some task, seems certainly true for number-concepts (cf Barsalou, 1987, 1990, 1993).

What we do suggest, and hope to have demonstrated convincingly, is that numbers, though special in some respects, are treated by the mind essentially like other mental objects, such as words or pictures. This also means that there are many kinds of variables that may , each in its own way, have contributed to the establishment of the hierarchy which, in general, seems to be there. Above, we have discussed some properties of the number system itself, which does not treat its members as equal. In general, these properties will determine how often a number will be met, and in how many different contexts. Moreover, smaller magnitudes can be better represented in concrete forms, which are used to acquaint children with the meaning of numbers and number-words. (See also Dehaene, 1992, and Gallistel & Gelman, 1992). Other 'privileged' numbers, such as multiples of 5 and 10, are used in dealing with money in most countries. Multiples of 12 are used for measuring time. Multiplication Tables are taught and practiced in school. Certain numbers, then, are favoured by their own properties, which make them more suitable for being used. General language frequency counts, reflecting the combined effort of many peoples minds, could be considered to sum up the long term effects of all such differences.

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Appendix 1

Lists of numbers used in the experiment.

	list 1	list 2	list 3	list 4	list 5
a	46	47	48	49	57
	65	64	63	13	14
	73	21	22	29	24
	80	79	59	77	30
	89	88	40	41	42
	1	2	3	4	7
	95	94	91	58	78
b	61	5	6	9	8
	43	68	67	66	69
	27	74	25	26	75
	35	32	33	34	31
	44	82	81	15	83
	54	51	52	50	90
c	12	60	10	11	62
	19	17	18	20	16
	100	71	70	28	23
	76	99	37	38	39
	87	86	85	84	45
	92	93	55	56	53
	72	36	98	97	96

Appendix 2

Numbers 1-100 as divided into five non overlapping sub-categories

Singles (n = 9)

1,2,3,4,5,6,7,8,9

Teens (n = 10)

10,11,12,13,14,15,16,17,18,19

Doubles (n = 8)

22,33,44,55,66,77,88,99

Large Tabled (n = 29)

20, 21, 24, 25, 27, 28, 30, 32, 35, 36, 40, 42, 45, 48, 49, 50, 54, 56, 60, 63, 64, 70, 72, 80, 81,90, 84, 96, 100

Others (n = 44)

23, 26, 29, 31, 34, 37, 38, 39, 41, 43, 46, 47, 51, 52, 53, 57,58, 59, 61, 62, 65, 67, 68, 69, 71, 73, 74, 75, 76, 78, 79, 82, 83, 85, 86, 87, 89, 91, 92, 93, 94, 95, 97, 98