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INTERDEPENDENCIES BETWEEN LONG-TERM, SHORT-TERM AND SENSORY MEMORY

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M A G N E   N Y B O R G

INTERDEPENDENCIES BETWEEN LONG-TERM, SHORT-TERM AND SENSORY MEMORY:

A theoretical evaluation and discussion, based upon analyses of some relevant empirical studies.

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ABSTRACT:

This article focuses upon interdependencies between memory units; i.e., interrelationships which have not been sufficiently highlighted in literature. It is proposed, here, that differences in reports of S-units in an SM-experiment reflect not only differences in SM-capacity, per se; but also possible differences in the LTM-bases for coding and reporting such units. Similarly, observed differences in STM may reflect differences in LTM-bases for chunking or coding, besides other possible differences (e.g., in rehearsal strategies). Thus STM is considered an important factor in perceiving within a context. Since LTM-content and -organization as educational goals can be influenced by teaching or instruction, these notions have clear educational implications.

I. INTRODUCTION.

In contemporary research within the areas of (perception, learning, and) memory, three main categories of memory have been labelled and thus pointed out; i.e., 1) sensory memory (SM), 2) short term memory(STM), and 3) long term memory (LTM). These units of memory have been represented by separate "boxes" in recent information-processing theories or models.

This fact, and the fact that the different units have been separately investigated,has led to a possible conception of memory as divided into three distinct units, the interdependencies of which have scarcely found representation in several recent models of memory.

Perception, learning, memory.

In this paper, possible interrelationships between memory units will be the focus of attention. First, however, the construct of memory should be briefly related to those of perception and learning.

Perception.

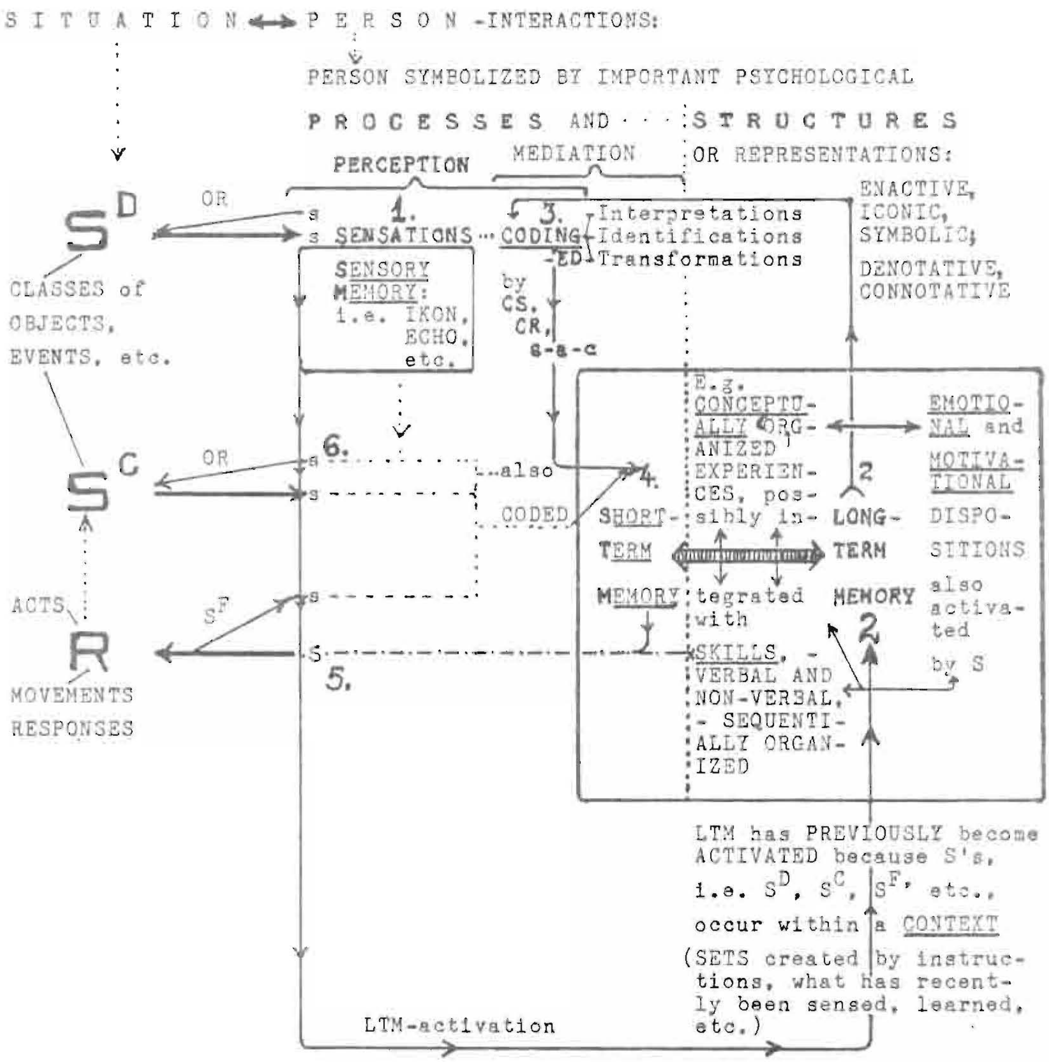
Thus, nothing can be remembered by a person unless he has somehow perceived it. The word memory refers to "something" which remains or is retained - for a shorter or longer time interval - within the person after a presentation and perception has terminated; i.e., is retained of what has been perceived. Both perception and memory denote theoretical constructs, inferred from observations of the person's behaviour.

Learning.

Learning refers to experiences somehow perceived and stored. Thus learning can be theoretically defined, in part, by reference to storage or memory; not by every kind of memory, however. Since learning usually refers to "relatively permanent changes (in behaviour)", only LTM and learning can be conceived of as different perspectives, used to describe much the same phenomena. Learning denotes experiences at the time when they are made (perceived) and stored - the acquisition process - while LTM denotes structures or representations of those experiences

Fig. 1

MN-80



OR - orienting responses or acts: Turning head, following contours with eyes, oral orientational acts, manipulations, etc.
S^F - feedback stimuli from the person's own acts.
S^D - discriminative stimuli; S^C - stimuli consequent upon the response
CS - coding systems; CR - coding responses; s-a-c - stimulus-as -coded
1 CONCEPTUALLY ORGANIZED - class concepts, organized into conceptual SYSTEMS by means of language skills.

within the person; i.e., structures which can be activated to what the person remembers, thinks, and - consequently - can do.

Constructs interrelated

The constructs so far named can be interrelated by a model like the one depicted in Figure 1 (NYBORG, e.g., 1978, a,b; 1980, a,b). In this model of assumed processes and structures within a learning and remembering person, coding (3) refers to an interpretation (identification, transformation, etc.) of differently sensed stimulus input (1.1) in terms of LTM-stored experiences previously made by the person (2); thus, LTM-stored experiences can reasonably be thought to become activated by present stimuli (OR- s, S^D, S^F, and S^C). Sensory memory (1.2) denotes the retention of (uncoded) information until it can be coded; that is, if it can be coded (or assimilated) by the person.

II. SENSORY MEMORY AND LTM.

Terminology and subdivisions.

Sensory memory has been differently denoted as

- very short-term memory (WICKELGREN, 1977, p. 206)
- perceptual trace (DEESE & HULSE, 1967, p. 396)
- primary memory (ELLIS, 1970)
- sensory register (ATKINSON & SHIFFRIN, 1968)
- after-images (SPITZ, 1973)

and has been subdivided according to sensory modality into "iconic" and "echoic" SM (NEISSER, 1967). Astonishingly, the important kinesthetic sensation and sensory memory has not been much investigated.

Another subdivision, which is partly related to conditions of stimulus presentation, is that of 1) persistence (of vision), 2) positive afterimages and 3) negative afterimages (WICKELGREN, 1977). Afterimages have been most clearly demonstrated within the visual sense and seem to depend upon variables like presentation time, background light-intensity, and colour.

Earlier notions

The term sensory memory can probably be coordinated with the term "molar stimulus-trace", used by C. L. Hull (e.g., 1952). Empirically, the notion of a molar stimulus trace has been based, by HULL, upon the most favourable time interval (approx. 0.5 sec.) between CS and UCS in many PAVLOVIAN classical conditioning experiments. SM can probably be coordinated, also, to the closed neural systems, reverberatory circuits, used by HEBB (1949) to explain what he denoted a short term memory.

II.1 Experimental procedure. Interpretation of results.

Empirical bases: Pioneer experiments

The commonly used reference or pioneer experiments demonstrating iconic sensory memory are those performed by SPERLING (e.g. 1960), AVERBACH & SPERLING (1961), AVERBACH & CORIELL (1961), etc.

A typical experimental situation includes

1) an instruction - or explanation of the experimental procedure,

2) a very brief presentation of a matrix of consonant letters - all at the same time - like those presented below:

X M R J	or	K D Z	B J L
P N K P		N S P	W G X
L Q B G		T M R	C V D
12		18	

The presentation is of such a brief duration (e.g., 0.05 sec.) that a coding of all letters within the presentation interval is impossible; the omission of vowels likewise makes a coding qua "chunking" of letters into syllables or words impossible. At the end of the presentation interval, or shortly after,

3) a signal, often given in another sensory mode, indicates either

   3.1) that all the presented letters should be (coded and) reported, if possible; that is, "whole report", or

   3.2) that one randomly chosen letter (or row of letters) should be reported by the subject; i.e., "partial report". In the latter case, also the location - in the matrix - of the letter(s) to be reported, is signalled.

Since all letters in the matrix have the same probability of becoming sampled, and the subject does not know which, he must "keep" all of them in SM until he is allowed to "read out" the one signalled: According to this rationale, the partial-report-probability is multiplied by the total number of letters in a matrix in order to estimate the number of letters kept in SM until the "read-out" signal was given and the report started. E.g., if a mean of 80 out of 100 subjects - in the partial report condition - correctly report each letter pointed out by location, the estimate is, in terms of an eighteen-letter matrix, (18·0.80) 14.6 letters.

If the "read-out" signal is given in the same sensory modus and in the location of the previously presented, to-be-reported letters, the signal has proved to completely erase SM for those letters (AVERBACH & CORIELL, 1961).

This seems to mean that when a new S^D reaches the retinal area recently stimulated, this new stimulus erases the SM for the preceding one.

Finally, the read-out signal is given either immediately or after short delay intervals.

Whole report. The rationale for evaluating the results seems to be that during the efforts to "read-out" or code all letters (whole report), a major part of the letters will be forgotten. In fact, it has been shown empirically that only a minor part of the letters can be reported under these conditions.

Partial report. During the partial report procedure, coding activity does not interfere with SM for the other letters. Since all letters have the same probability of being pointed out, a high mean proportion of reports is indicative of the capacity of SM. Thus SM is operationally defined by the difference between "whole report" and "partially reported" items of a matrix.

In Fig. 2, taken from AVERBACH & SPERLING (1961), it can be seen that the whole report, or baseline number of letters

a) is not affected by the actual delay intervals, and

b) that the number of letters approximates the memory span

(Miller, 1956: 7 $\pm$ 2 chunks).

Fig. 2

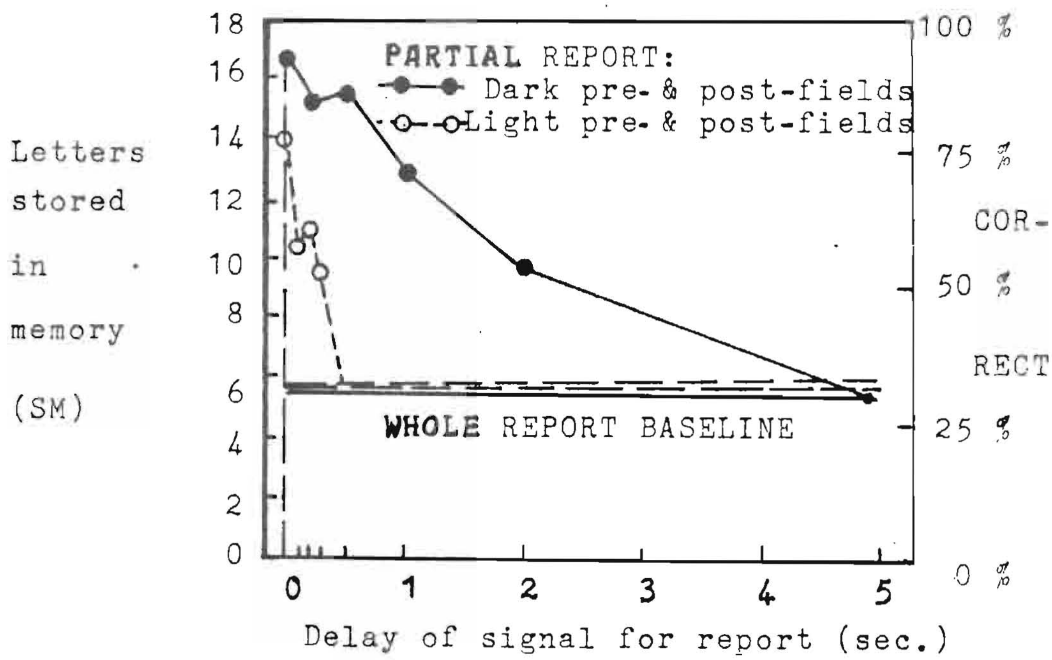


Figure 2 : Decay of iconic sensory memory under two conditions of stimulus intensity (After AVERBACH & SPERLING, 1961).

The partial report excess, however, decreases rapidly from a high supra-span number of items to a whole report number. This happens in half a second, when the background field is lighted both before and after presentation. Thus, it can be seen that the difference between partial and whole report numbers of letters has been used as a quantitative estimate of iconic SM. It can be seen also that SM is of very short duration when light conditions are similar to those of daily life - including ordinary reading conditions.
SM - possibly in the form of positive and negative after-images - is of longer duration when stimuli are more intensive against a dark pre- and post-field.

II.2 Discussion

It should be noticed that subsets of letters, usually highly over-learned by the adult subjects who participate, are utilized in the standard experiment. Thus, units of LTM-stored verbal skills (Fig. 1), which are presumed to become quickly activated for a coding and verbal report, have repeatedly been utilized in estimates of sensory memory. Thus, it is probably impossible to estimate SM except by means of material with which subjects are familiar; i.e., units which in advance are represented in LTM and can be used to code (or identify) and report what has been presented.

This notion must be taken into consideration when persons or subgroups are compared with regard to SM. Thus, if the verbal skills are learned to different levels of "automation" (FITTS, 1964), in different persons or subgroups, this LTM-difference should be expected to reflect in measures of sensory memory. Since measures of SM have been used to compare retarded with normal readers, for instance, one can wonder what is really being compared, SM or LTM.

Conclusion. The significance of SM is, among other things, that it makes possible a delayed coding of stimulus components when stimuli are of very short duration or are brief and very complex; further that SM can bridge gaps between discrete events (visually: letters or phonemes integrated into words, single pictures into movies, etc.). The rapidity and sequence of coding can be considered to depend upon individual LTM-content and -organization, however.

Thus, as far as measurement is concerned, SM cannot be considered independent of LTM-organization and -content (Fig. 1). In this sense it is influenced by educational practice; i.e., the teaching-learning history of the person evaluated.

III. SHORT-TERM MEMORY (STM) AND LTM.

Since short-term memory can be defined as a memory for coded input units, and the coding process depends upon what has become activated of LTM-content, STM can be viewed as indirectly reflecting LTM-contents. The reason for maintaining a distinction between STM and LTM seems to be the notions of memory span, subspan, and supra span, therefore.

III.1 Memory span.

Operationally, memory span can be defined as follows: Sets of items, each of which is presumed to be learned and thereby known by the person tested (i.e., LTM-content)are presented in a sequence, one at a time, to the person. The items most often used are digits or consonant letters spoken to or seen by the subject. They are presented in combinations or sequences which are presumed to be unfamiliar to or not-learned by the person, however.

In the latter respects, memory span test conditions appear to be similar to those of testing SM. The differences compared to a test of sensory memory are that 1) digits, letters or other units are presented in a sequence, one at a time, and 2) at a rate that permits a continuous coding and rehearsal.

Immediate memory.

Immediately after a presentation of a sample of items, the tested person is expected (mediated by a preceding instruction) to reproduce or recall all of them. The test of memory span usually starts with a low number of items which is increased until the subject is no longer able to reproduce the whole sequence.

Having inspected a wide range of data on STM, MILLER (1956) focused upon the "magic" number of 7 $\pm$ 2 coding units or chunks, which seems to reflect what most adult persons are able to recall after a single presentation; that is, of presumably unrelated items. SPITZ (1973) has similarly focused upon the number of 6 for normals and 3-4 items for retardates.

By using a somewhat different experimental technique, ELLIS (1970) has shown that STM-data are similar to those of serial learning, when plotted by curves (Fig. 3); i.e., the first items (primary) and the last items (recently presented) are most frequently reproduced or reported. Thus primacy and recency, respectively, seem to favour retrieval or recollection.

Failure to recall the first items in a row (primacy "deficit") has been interpreted to indicate a rehearsal deficit. "Primacy deficits" in this sense, have been detected in both normal and retardate lower-MA children; and this fact has been interpreted to mean that they lack or apply ineffective rehearsal strategies (ELLIS, 1970).

Fig. 3.

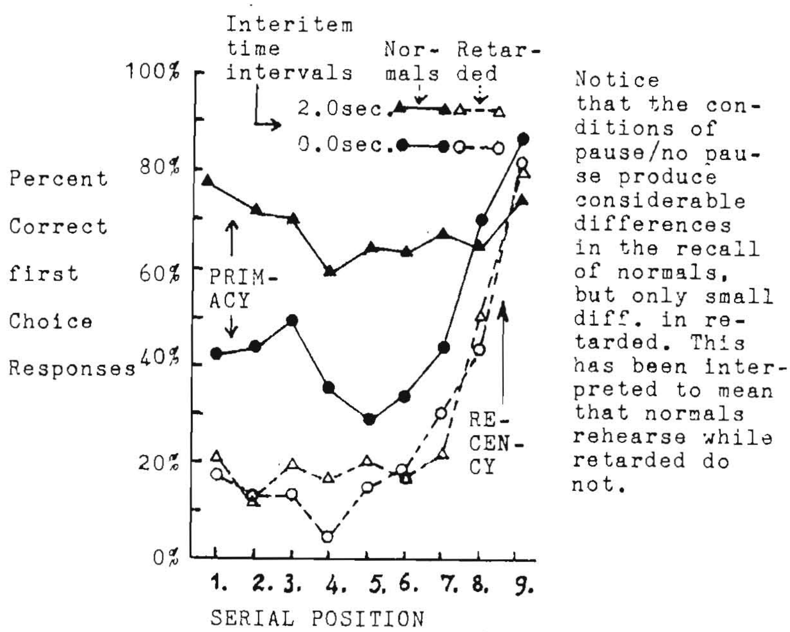


Figure 3: Performance of normals and retarded persons on a STM-task involving 9 items (e.g., 9 digits), presented either with a pause of 2 sec. or no pause between each item. Items are presented in a row, one at the time. After an entire 9-item presentation, the S is required to point out the position for a specific "probe" item. After ELLIS, 1970

Retardates, when compared with equal-CA-children, reproduce a lower number of first and middle items; no difference is found in the most recently presented items, however (Fig. 3).

These data are further interpreted to mean that SM is normal, based upon recency data, but that STM is unfavourably influenced by a lack of or ineffective rehearsal strategies, in retardates.

This notion is supported by data collected by BELMONT & BUTTERFIELD (1971); thus, they have shown that retardates lack the ordinary pattern of pauses during memorizing that is indicative of rehearsal.

Though ELLIS (1963) has claimed that LTM is normal in retardates, the data just referred to can be additionally interpreted to mean that the required verbal skills have not been learned (i.e., LTM-stored) to the same criterion of overlearning or automation (FITTS, 1964) by retardates as in CA-equal normals. Thus, the reader who has taught retarded children, knows that the level of reading skill and amount of reading experiences (frequency of occurrence), is usually far lower in retarded children than in normal children of the same CA. The possibility exists, therefore, that if the level of LTM-organizations is raised, a corresponding increase in STM-capacity should be expected.

The latter notion, contrasted with the assumption made by ELLIS, has been one important point of departure for both prophylactic and remedial teaching given to lower-MA children; and this has appeared to be a fruitful approach (NYBORG, 1978, a, b; 1980, a, b). The work has also included an extension of the children's capacity for rehearsal, however.

III.2 Sub-(memory-)span STM.

In tests of memory span, the span denotes the highest number of items, heard or seen, which a person is able to report immediately after a first and single presentation; i.e., when relatively undisturbed by inwardly or outwardly distracting events. In tests of sub-span, the focus of attention is 1) upon the time (or delay) interval between presentation and the signal for reporting or reproducing; and 2) the activity taking place in the person between those two events.

Thus, in PETERSON & PETERSON's (1959) pioneer experiment, a sub-span number of consonant letters (e.g. JCF) would be presented. In advance, subjects have been instructed to count in a highly unusual manner, during the delay interval:

1) Presentation:	2) Count backwards:	3) Signal for reproduction
ICF	364 - 361 - 358.....	

It will be understood that the counting activity is of such a kind that the person must probably focus his attention upon it, thus preventing a rehearsal of the presented items. The counting activity is analogous to events - in daily life - which interfere with events which have to be retained in short term memory in order to stay within a given and chosen context.

Such interfering events can be within the person (e.g., emotional reactions) or events taking place concurrently in the person's environment. A (possible) person-variable within this context is the person's capacity for resistance against distracting incoming stimuli (e.g., interest, based upon knowledge). Another (possible) person-variable is his capacity for producing "supporting feelings" during STM retention intervals (WHITE & WATT, 1963).

Figure 4 shows that a subspan number of three consonant letters, constituting a three-unit rather than a one-unit whole (i.e., three chunks), is almost completely forgotten in 18 seconds when conditions are like those referred to above.

Figure 4 also shows, however, that an equal or even a higher number of letters can be retained under similar conditions, if the letters can be organized by the person into one articulated and meaningful word. In that case each letter is no longer a separate

Fig. 4.

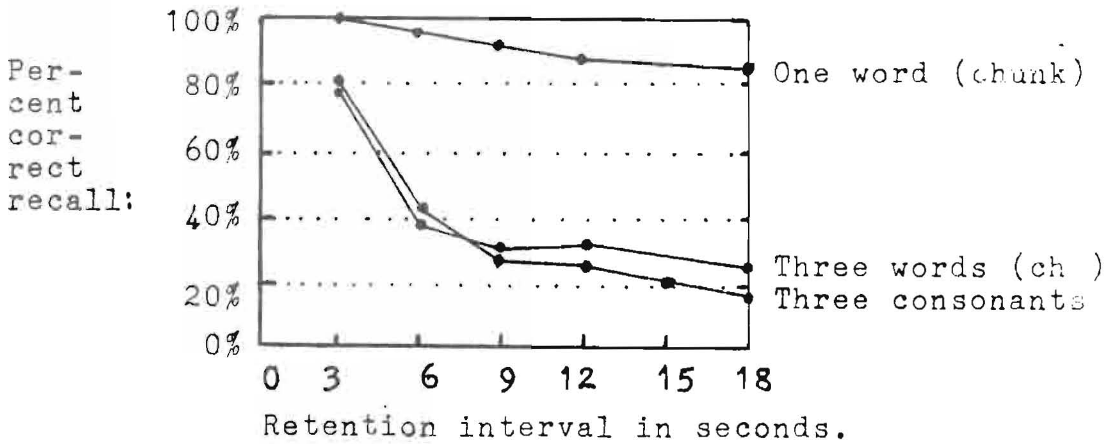


Figure 4: STM experiment: The recall of one word (or chunk) compared with three conceptually unrelated words and three consonants (or chunks). Data from MURDOCK,1961

coding unit, for the person; all letters are integrated to a whole, which constitutes the "chunk" or new coding unit. With this familiar word form are associated several word-meanings, in the person.

When three conceptually unrelated words are used, the forgetting curve is very much the same as that for three consonant letters, however (Fig. 4).

The next experimental step would logically be to use three conceptually interrelated words as stimuli within the same experimental settings: that is, three words that can easily be subordinated to the same superordinate name (e.g., red, green, blue (COLOURS)). The present writer has not seen that this kind of experiment has yet been performed.

It would represent an approximation to experiments concerned with "clustering in free recall" and "recall of conceptually ordered word lists", however. These subjects will be treated in the next section, labelled supraspan STM.

III.3 Supra-span STM.

Thus three conceptually interrelated words can be considered one "chunk", in terms of MILLER's (1956) construct; and a "cluster" within BOUSFIELD's (1953) terminology. The two words are clearly interrelated. Thus "chunk" and "chunking" seem to refer to the coding process; i.e., what happens in the person at the time of perceiving-learning. The word "cluster" has been used to denote possible results of chunking (organizing parts to a whole), as manifested in free recall data.

Chunking - and the possibly resulting clusters - are both dependent upon the person's LTM-content and -organization. Only when the person has learned and stored the words red, green, blue, etc., as names for COLOURS (i.e., as parts of a conceptual system), should he be able to code or chunk them by means of the word colour. In that case the single word COLOUR could be used to reconstruct the actual set of colour names or concepts.

These aspects of coding or organizing processes have been studied in supra (-memory) -span research (HORTON & TURNAGE, 1976, p. 161). The reason for calling it supra-span research is that it applies the memory space test technique, but with a modification of stimulus conditions that permits the able person to organize single items into larger coding units or chunks; i.e., in terms of superordinate category names. This, in turn, permits him to remember a supra-span number of presented items, immediately after even the first presentation.

Consider the following two lists of words, both of which contain 116 letters, the same 24 words, but only 6 chunks or superordinate coding units; that is, for persons who have learned and LTM-stored the necessary conditions for organizing or chunking.

Figure 5. Two lists of words, allowing the "able" person to organize 116 letters into 24 words; the 24 words into six coding units or chunks, possibly by means of superordinate words. Six units are

ordinarily within the memory span of adult persons:

	BLOCKED PRESENTATION	RANDOMIZED PRESENTATION
	red	red
	green	father
(COLOURS)	yellow	plate
	blue	south
	horse	horse
(DOMESTIC ANIMALS)	cow	window
	goat	sister
	sheep	knife
	north	north
	south	wall
(DIRECTIONS)	east	goat
	west	yellow
	father	mother
(FAMILY MEMBERS)	mother	fork
	sister	west
	brother	sheep
	wall	roof
(PARTS OF HOUSE)	roof	green
	window	brother
	door	spoon
	knife	cow
(EATING IMPLEMENTS)	fork	blue
	spoon	east
	plate	door

Blocked presentation

It can be seen that in the list providing "blocked" presentation, the words belonging to the same category are close in (space and) time. Short term memory can thereby provide a context which renders a conceptual organization by superordinate names possible.

When words are presented in a "blocked" way and are further organized to a conceptual hierarch or system, subjects have proved to remember twice to three times the memory span iddediately after a single presentation (BOWER, CLARK, LESGOLD , & WINZENZ, 1969).

Random presentation in clustering experiments

In the randomized list, words belonging to the same category are distributed at random over the entire list; they are more remote in time (and space), therefore, and they are separated by an activity (reading or hearing conceptually unrelated words) which in some respects resemble the activity introduced into sub-span experiments; i.e., activity that prevents rehearsal.

Repetitions are usually necessary in order to be able to detect categories and organize or chunk, accordingly, therefore; but retrieval during acquisition or learning trials is not identical to the serial learning of lists of conceptually unrelated words; and delayed (or LTM-) recall is better, both in terms of the number of words recalled and the manner of recall; that is, they are more "meaningfully" recalled, in a conceptually changed or clustered way as compared with the original list (e.g., BOUSFIELD, 1953).

III.4 Some conclusions. STM and context.

The experimental paradigms and results referred to in preceding sections, used to assess memory span, sub-memory-span, and supra-span, respectively, can all be said to support the notion that STM and LTM are not two distinct entities. Rather should STM be considered the activation by input stimuli to a process of specific components of LTM-structures or -contents (Fig. 1). This interpretation corresponds well with L. R. PETERSON's (1975) conception of STM as a working memory; i.e., the parts of LTM contents at momentary work.

This means that STM cannot be considered of fixed size, as might be suggested by the figures offered by MILLER (1956) and SPITZ (1973), and by memory span tasks, included in intelligence tests.

Thus 1) comparative research in STM (e.g. ELLIS, 1970), as well as subspan measures of STM, indicate that several factors in a person and his immediate surroundings can momentarily or more permanently influence STM-performance. In particular the person's "rehearsal strategies", based upon language functions (i.e., verbal skills and their common conceptual meaning components), are of importance for the limits of his STM; and it has been observed that rehearsal strategies can be changed by learning - or influenced by teaching (A. BROWN, 19 ; LYNGSTAD & NYBORG, 1974).

2) Supra-span research shows that within the limits of 7 ± 2, the amount of information that can be stored for rehearsal and later short-term or long-term reproduction, depends upon the coding unit or "chunk" size available for a person at a specific time and in a particular field of information. Since the coding unit by definition reflects a person's LTM-stored experiences, and particularly his conceptual and verbal skill capacities (Fig 1; e.g. BOWER, 1975; WICKELGREN, 1977, and others), learning can again be regarded as an important factor in change of STM capacity. That is, concepts and skills can be learned.

The importance of an effective short-term memorization can perhaps best be understood in terms of the construct of context, however. Thus, each object or event is usually perceived or interpreted - by a person - within the context of simultaneously precedingly "presented" objects or events. Especially when the context is provided by a sequence of events, preceding events must for a short time be remembered. This is particularly important when preceding stimulus-events cannot be "perceptually" returned to, as in listening to a speech, looking at a movie, passing a scene by a fast train, etc. In reading return to previous text is possible; many returns will considerably retard the reading process, however.

In such cases a fast coding, and a coding in terms of large "chunks" are of importance for staying within a context.

IV. CONCLUSIONS: LTM CONCEIVED AS A STRUCTURAL BASIS FOR SEVERAL PSYCHOLOGICAL PROCESSES. SOME IMPLICATIONS FOR TEACHING.

IV.1 LTM considered as a structural basis for psychological processes.

The model exposed in Figure 1 (page 2) suggests that Long Term Memory - i.e., what has previously been experienced, organized and stored for a long time by a person - largely determines his perception, his short-term memory and thinking (working memory), and his behaviour or performances.

LTM → perception and SM.

Perception - of course - includes the possible coding of information given in very brief presentations (as phones involved in fast speech). The resulting sensations are likely to be quickly erased by succeeding events stimulating the same areas of receptors of sense organs. A fast coding, frequently in terms of highly automized, verbal skills and their conceptual meaning components is important, therefore. Thus, if coding takes place slowly and faultily, much information may be lost by the person. That is, the sequentially ordered context, by which new events should be coded, is disturbed or broken for him.

LTM → perception as a categorizing process

Perception - or coding in perception - reflects an adequately developed LTM in frequently being a categorizing process (HEBB, 1949; BRUNER, 1957 ; NYBORG, 1980, a, b). Thus, in being able to apply names to our experiences, - i.e., by describing or reporting them to ourselves or to others, we assign them class memberships by utilizing LTM-stored class concepts and verbal skills. This, of course, happens since most words in a language name classes of phenomena; that is, in those who have learned the adequate meanings of words.

LTM → analytic and selective perception

Categorization or classification, in turn, involve an analytic and selective coding of objects and events, since we categorize - assign class memberships - according to partial similarities and differences, possibly analyzed and selected (NYBORG, 1978, a,b; 1980 a,b). Thus an adequate analysis, defined by the flexible application of stimulus-relevant coding systems, appears to be necessary for a communicable categorization, therefore.

LTM → "depth" of analysis → LTM.

According to CRAIK & LOCKHART (1972) a complete analysis is reversely important also for storage of information. Thus, the greater the "depth" or completeness of analysis, partly dependent also upon the time available, the better or more permanent will the storage be. Preceding this cause-effect-sequence is another chain, recently pointed out, thus providing a positive circular chain: 1) An adequate LTM-content and organization → 2) a better perception → 3) better STM- and LTM-storage.

Different kinds of stimuli perceived.

Perception - involving the coding of sensations (Fig. 1) - includes the coding of stimuli that precede an act and possibly provide "occasions" for doing that act (S^D), stimuli produced by and accompanying movements and acts (S^F and s's, produced by OR and R), and the coding of stimuli that occur as consequences of acts (S^C). The latter can be classified also according to their incentive value for the person, either positive or negative in some degree. Incentive values, in turn, reflect the person's emotional and motivational "dispositions", also stored in his LTM.

LTM → STM

It has been demonstrated in section III that short-term memory can most fruitfully be regarded as a sequential activation of LTM-stored experiences or units; i.e., a short-term memory for coded units. The number of presented units that can be made available and reproduced by the person shortly after a terminated presentation, seems to depend upon a set of factors; e.g., the coding units or chunk sizes applied by the person, the opportunity given for rehearsal, and the person's active participation in a situation in terms of rehearsal. Thus, within a possible limit of 7 ± 2 units, probably dependent upon both freedom from distracting stimuli and opportunity to rehearse, the coding unit size determines the amount of information stored and possibly reproduced by a person.

Thus, individual LTM-content and -organization - a product of both learning and teaching -learning - provide the bases for individual STM-capacity.

LTM - acting, performing.

Finally, the behaviour of a person, his acts or performances in most situations, can be considered to reflect sequentially ordered, LTM-stored skills, including of course verbal and other language skills. It complicates this picture that skills, implicitly or explicitly, are involved also in the coding and rehearsal processes discussed above.

IV.2. Implications for educational practice or teaching.

LTM is but another way of expressing "goals for educational practices or teaching"; or a person's knowledge, goals, and skills; or what a person has previously experienced (or perceived) and learned - stored.

Learning can take place in many kinds of interaction by a person with his environment (Fig. 1), and much is probably learned "by himself" or at least without a planned education. Interactions with other, more competent persons often include education, however, and teaching can be regarded as a professionally based arrangement of learning conditions.

In the preceding chapters it has been pointed out which "attributes" of LTM - i.e., which kinds of LTM organizations - can be thought to provide adequate perceptions, can facilitate and extend STM and thought, and can mediate adequate behavioural performances.

The conceptual and skill - especially language skill - organizations of LTM have been emphasized by the present writer, as they have been emphasized as fundamental by several others (e.g., HEBB, 1949; BOWER, 1975; WICKELGREN, 1977; L.R. PETERSON, 1975); the corresponding teaching of instrumental language functions should be weighted accordingly in educational curricula and practice. They would constitute significant components of "successful teaching" and "meaningful learning"; only such achievements can be expected to create comfortable feelings and favourable motivational dispositions toward the phenomenon of learning - in both teachers and those taught.

This, of course, is of greatest importance, since learning probably plays a far larger role in human development than in the development of any other species. And only "man" has been considered an "animal symbolicum", thus reflecting the centrality of the themes pointed out in this paper.

B V AN EXPERIMENTAL EVALUATION OF SUPRASPAN STM:

Six groups of four conceptually interrelated words freely recalled immediately after two different conditions of presentation.

The experiment presented in this section is related to the themes developed in chapter III.A.

V.1 Subjects and experimental conditions.

Nineteen advanced students of education participated in the experiment referred to here; and it was performed, mainly, during one lecture of learning psychology. The group of nineteen Ss was divided into two subgroups, each of which was separately subjected to one of the following two conditions of a supra-span STM-experiment:

Group 1
Condition 1

Group 1 (10 Ss) was given the task of recalling - by writing on response sheets immediately after the presentation - the lists of words denoted A-1 and B-1 in table 1 (p.22).

Group 2
Condition 2

Lists A-2 in table 1, which constitute random presentations of the words which are conceptually "blocked" in lists A-1 and B-1, were presented for immediate recall to group 2 (9 Ss).

The words were read for the subjects with a rate of approximately 40 words per minute, and the recall interval lasted until all Ss had stopped writing. Two response sheets, each containing 24 short lines for writing the words within a list, had been provided for each subject. A short instruction regarding the nature of the task (but not the nature of the lists), preceded the reading of the first list.

The original lists, containing the words written in Norwegian, and an example of the response sheets

Table 1 Word lists[1] used in a supra-span STM-experiment. -1 and -2 denote two conditions of presentation of the same words; i.e., a blocked and a random presentation, respectively:

BLOCKED PRESENTATIONS				RANDOM PRESENTATIONS	
LIST:	A-1		B-1	A-2	B-2
COLOURS	Red Green Blue Yellow	GEOGR. DIRECT-IONS	North West South East	Red Three White anemone Knife	North Ceiling Eight Sparrow
NUMBERS	Four Three Two One	Parts of ROOM	Wall Ceiling Window Door	Pig Table Two Yellow	Root Hearth Window East
FLOWERS	Violet Blue anemone White anemone Dandelion	NUMBERS	Nine Six Eight Seven	Violet Spoon Cow Chair	Nine Magpie Flower Oven
FURNITURE	Chair Table Bench Stool	FIRE-PLACES	Oven Hearth Chimney Barbecue	Four Green Sheep One	Wall West Leaf Door
Eating TOOLS	Knife Fork Spoon Tea-spoon	BIRDS	Sparrow Tomtit Magpie Crow	Fork Bench Dandelion Blue	Tomtit Chimney Seven South
Domestic ANIMALS	Cow Sheep Goat Pig	Parts of PLANTS	Flower Leaf Stem Root	Stool Goat Tea-spoon Blue Anemone	Barbecue Stem Crow Six

1 The words are translated from Norwegian. In Norwegian the corresponding words often are shorter and never consist of two separate words, as in some cases above.

Every list - in Norwegian - consist of 24 words and an approximately equal number of letters, therefore.

applied, are presented in the appendix. It can be seen that list A-1 contains only 24 words in Norwegian, while the corresponding number is 26 in English. The number of letters is also lower, in the Norwegian word lists.

V.2 Experimental results.

The observations made in terms of numbers of words recalled and their degrees of clustering (lists A-2 and B-2), are presented in table 2 (p.24).

The processing of data show that a) means are higher and b) standard deviations are lower in group 1 than in group 2; and the differences between means are significant at high levels of confidence.

In condition 1 "chunking" and corresponding clustering cannot take place, since the words had a priori become category- "clustered" or "blocked". In condition 2 clustering occurs in seven out of nine subjects, and the amount of clustering is - at least partly - positively correlated with the number of words recalled. In two Ss this general pattern is broken. Thus, their recall take place without clustering; that is, words were recalled in approximately the same sequence as in the presented lists. In spite of this fact, a mean number of words was recalled. This was an unexpected result.

V.3 A short discussion. Educational implications.

It can be seen, in condition 2 data, that a considerable amount of clustering can take place even after a single presentation. This, of course, can only occur in persons who have learned and LTM-stored the concepts necessary

Table 2: Written, free and immediate recall of lists consisting of 24 conceptually inter-related words (6 super-ordinate categories), presented auditively to students of education (see lists presenteed at page 30).

	Lists: Subjects	A-1 X	In-trusions[1]	B-1 X	In-trusions	SUM X	Degree of category clustering:[2]
BLOCKED PRESENTATION: List A-1 B-1, 10 subjects	B-1	23	0	23	1	46	This condition involves an a priori clustering or clustered presentation.
	B-2	24	0	19	1	43	
	B-3	21	1	18	2	39	
	B-4	23	0	22	0	45	
	B-5	23	0	19	0	42	
	B-6	20	1	20	0	40	
	B-7	24	0	23	1	47	
	B-8	23	1	17	2	40	
	B-9	22	1	20	0	42	
	B-10	24	0	19	1	43	
	SUM X_B	227	4	200	8	427	
	$\bar{X}_B$	22.7		20.0		42.7	$\bar{X}_B$ = 21.35
	SD	1.37		2.05		2.67	
RANDOM PRESENTATION: Lists A-2 B-2, 9 subjects	Lists: Subj.	A-2 X		B-2 X			
	R-1	11	0	14	2	25	2 Much
	R-2	24	0	20	1	44	3 Very much
	R-3	13	1	13	0	26	3
	R-4	13	0	12	1	25	2
	R-5	12	0	15	2	27	0 None
	R-6	18	0	20	0	38	3
	R-7	19	2	19	2	38	3
	R-8	14	0	16	0	30	0
	R-9	12	2	11	0	23	1 A little
	SUM X_R	136	5	140	9	276	
	$\bar{X}_B$	15.1		15.6		30.7	$\bar{X}_R$ = 15.35
	SD	4.31		3.44		7.44	
DIFFERENCES and tests of diff.	$D_{\bar{X}_B - \bar{X}_R}$	7.6		4.4		12.0	
	t	5.30		3.44		4.78	
	df	17		17		17	
	$p <$	.005		.005		.005	

1 INTRUSIONS : Wrong words, belonging to correct category, used by the subject

2 Four degrees: o: None; 1: A little; 2: Much; 3: Very much

Notice: Memory span: 7 ± 2; Random: 15.35; Blocked: 21.35

for organizing (chunking) or re-organizing the word lists. Or, said in other words: These results can not occur unless the facilitating conceptual organizations are parts of the preparedness or readiness for solving the task in a supra-span manner; and such better recall can be considered a positive incentive for the person.

Pure associations between word forms can be thought to contribute, however, as can the possible production of "images" (PAIVIO, 1971). The relative contribution can not be evaluated, based upon the present data.

The relatively large amount of clustering is of considerable interest, since it is ordinarily measured in delayed free recall and after repeated presentations of the word lists.

The difference between blocked and random presentations can probably best be explained in terms of contextual restraint or facilitation, respectively, upon the person's recoding by super-ordinate words.

Thus, in condition one - i.e., immediate recall after blocked presentation - the temporarily close occurrence of words belonging to the same superordinate category probably facilitates the recoding and rehearsal by superordinates.

In condition two, the random presentation has features in common with a sub-span experiment.That is, new words intervening between the words belonging to a specific category, can be thought to have very much the same function as the counting activity; i.e., that of preventing effective rehearsal and recoding.

In spite of these possibly disturbing effects, clustering by superordinate words seemed to occur in most group 2

Ss, and a relatively high number of words were recalled also in this group.

I Memory span for conceptually unrelated words estimated (MILLER, 1956) 7 ± 2

II Supra-span:
.1 Random presentation of 24 conceptually related words $\bar{X}=15.35$

.2 "Blocked" presentation of the same 24 words $\bar{X}=21.35$

The memory span number of words can be thought of as an estimate of recall in persons who have not learned or are not able to transfer the learned bases for recoding by superordinates.

Educational implications.

The educational implications of the presented experiment and the subsequent discussion are of at least three kinds:

1) In terms of presentation sequence, when conceptually inter-related words are involved;

2) in terms of the student's preparedness or learned readiness to organize or code sequentially presented words by conceptually superordinate words; and

3) in terms of teaching-learning conceptual organizations and their verbal-skill counterparts.

Thus, when category-like words are presented in sentences or lists, they should be - and are probably most often - presented in "blocks". Further cues for "grouping" can be given by accentuations and pauses, however; and the superordinate word can be added, if the listener is suspected to be "low" in using superordinates as part of his coding and rehearsal strategy.

When teaching readiness for conceptual coding or chunking, the superordinate words should repeatedly be used, by the teacher as well as by the student, to intergrate sub-ordinate words into conceptual systems or structures (NYBORG, 1978, 1, chapt. VI).

REFERENCES

ATKINSON, R. C. & SHIFFRIN, R. M. : Human memory: A proposed system and its control processes. In K. W. SPENCE & I. I. SPENCE (eds.): "The psychology of learning and motivation, Vol. 2, New York, 1968.

AVERBACH, E. & CORIELL, A. S. : Short term memory in vision. Bell Sys. Techn. J., 1961, 40, 309-328.

AVERBACH, E. & SPERLING, G. : "Short-Term Storage of Information in Vision", in CHERRY (ed.): Information theory, papers from symposium on information theory, London, 1961, pp. 196-211.

BELMONT, J. M. & BUTTERFIELD, E. C. : Learning strategies as determinants of memory deficiencies: Cognitive Psychology, 1971, 2, 411-420.

BOUSFIELD, W. A. : The occurrence of clustering in the recall of randomly arranged associates. J. Gen. Psycho., 1953, 49, 229-240.

BOWER, G. H. : Cognitive Psychology, in ESTES (ed.): Handbook of Learning and Cognitive Processes, Vol. 1, 1975.

BOWER, G. H., CLARK, M. C., LESGOLD, A. M. & WINZENZ, D. : Hierarchical retrieval schemes in recall of categorical word lists. J. of verbal learn. and verb. behavior, 1969, 8, 323-343.

BROWN, A. L. : The role of strategic behavior retardate memory, in ELLIS (ed.): International Review of Research in Mental Retardation, Vol. 7, New York, 1974.

BRUNER, J. S. : On perceptual readiness. Psychol. Rev., 1957, 64.

CRAIK, F. I. M. & LOCKHART, R. S. : Levels of processing: A framework of memory research. J. verbal learn. and verb. behavior, 1972, 11, 671-684.

DEESE, J. & HULSE, S. H. : The psychology of learning. Third ed., Tokyo, 1967.

ELLIS, N. R. : The stimulus trace and behavioral inadequacy, in ELLIS (ed.): Handbook of mental deficiency, New York, 1963, 134-158.

ELLIS, N. R. : Memory processes in retardates and normals, in ELLIS (ed.): International Review of Research in Mental Retardation, Vol. 5, New York, 1970.

FITTS, P. M. : Perceptual-motor skill learning. In MELTON (ed.): Categories of human learning, New York, 1964.

REFERENCES, continued

HEBB, D. O. : The organization of behavior. A neuropsychological theory. New York, 1949. Third print, 1963.

HORTON, D. L. & TURNAGE, T. N.: Human learning. Englewood Cliffs, New Jersey, 1976.

HULL, C. L. : A behavior system. New Haven, 1952.

LYNGSTAD, T. & NYBORG, M. : Rapport om et treårig spesialpedagogisk felteksperiment (Report on a three-year, special educational field experiment). Institute for Educational Research, University of Oslo, Oslo, 1977.

MILLER, G. A. : The magical number of seven, plus or minus two: Some limits on our capacity for processing information. Psychol. Rev., 1956, 63, 81-97.

MURDOCK, B.B. jr. : The retention of individual items. J. Exp. Psychol., 1961, 62, 618-625.

NEISSER, U: : Cognitive psychology. New York, 1967.

NYBORG, M. (1978, a) : Læring, Begrepslæring, Begrepsundervisning (Learning, Concept learning, Concept teaching). Institute for Educational Research, University of Oslo, Oslo 1978 (a).

NYBORG, M. : Summary of a special educational research project with mild and borderline cases of mentally retarded children. Institute for Educational Research, Report nr. 8, 1978. University of Oslo, Oslo, 1978 (b).

NYBORG, M. et al. (1980, a) : Individualized teaching - for communicative social participation and for language-mediated transfer: ..... A paper delivered to the Trondheim researchers' seminar on individualized teaching. Institute for Educational Research, University of Oslo, Oslo, 1980 (unpublished).

NYBORG, M. et al (1980, b) : Teaching for language-mediated, conceptual transfer and for communicative social participation: A model for teaching basic, speech-mediated conceptual systems, theoretical reasons for doing it, and a set of empirical applications...... A paper prepared for the EASE congress taking place in Helsinki, August 1980. Institute for Educational Research, University of Oslo, Oslo, 1980 (unpublished).

PAIVIO, A. : Imagery and verbal processes. New York, 1971.

PETERSON, L. R. : Learning. Glenview, Illinois, 1975.

PETERSON, L. R. & PETERSON, M. J. : Short term retention of individual verbal items. J. Exp. Psychol., 1959, 58, 193-198.

REFERENCES, continued.

SPERLING, G. : The information available in brief visual presentations. Psychol.Monograph, 1960, 74, no. 498.

SPITZ, H. H. : Consolidating facts into the schematae of learning and memory of mental retardates. In ELLIS, (ed.): "International review of research in mental retardation", Vol. 6. New York, 1973.

WHITE, R. W. & WATT, N. F. : The abnormal personality, fourth ed. New York, 1963.

WICKELGREN, W. A. : Learning and memory. Englewood Cliffs, New Jersey, 1977.

A P P E N D I X

LISTER AV ORD, BENYTTET I ET SUPRA-SPAN KTM-EKSPERIMENT; TO PRESENTASJONS-betingelser, KATEGORI-ORDNET og RANDOMISERT:

KATEGORI-ORDNEDE LISTER:				RANDOMISERTE LISTER:	
OVERORDNET NAVN:	A.1	OVERORDNEDE NAVN:	B.1	A.2	B.2
FARGER	Rød	Geogr. RETNINGER	Nord	Rød	Nord
	Grønn		Vest	Tre	Tak
	Blå		Sør	Hvitveis	Åtte
	Gul		Øst	Kniv	Spurv
TALL-ORD	Fire	DELER AV ROM/HUS	Vegg	Gris	Rot
	Tre		Tak	Bord	Peis
	To		Vindu	to	Vindu
	en		Dør	Gul	Øst
BLOMSTER	Fiol	TALLORD	Ni	Fiol	Ni
	Blåveis		Seks	Skje	Skjære
	Hvitveis		Åtte	Ku	Blomst
	Løvetann		Sju	Stol	Ovn
MØBLER	Stol	ILDSTEDER	Ovn	Fire	Vegg
	Bord		Peis	Grønn	Vest
	Benk		Kamin	Sau	Blad
	Krakk		Grill	En	Dør
SPISE-REDSKAP-er	Kniv	FUGLER	Spurv	Gaffel	Kjøttmeis
	Gaffel		Kjøttmeis	Benk	Kamin
	SKJE		Skjære	Løvetann	Sju
	Teskje		Kråke	Blå	Sør
HUSDYR	Ku	PLANTE-DELER	Blomst	Krakk	Grill
	Sau		Blad	Geit	Stengel
	Geit		Stengel	Teskje	Kråke
	Gris		Rot	Blåveis	Seks
	102 bokst.		103 bokst.	102 bokst.	103 bokst.
	24 ord		24 ord	etc.	etc.
	6 kategorier eller chunks		6 kategorier eller chunks		