Memory

Memory is an extraordinary phenomenon in nature. Our memory bank contains our lexicon, language knowledge, our complete knowledge of facts, recall of our life experiences, human as well as all motor skills from walking and talking to swimming and playing tennis. Somehow our memory stores these kinds of information in a way that they are always accessible and easily retrievable. The easiest assumption would be that the brain can store as many bits as it has nerve cells. This is not the case. The brain encodes memories and stores them, causing the pattern and the excitability of countless synaptic links to change.

Our iconic (Gr. ikon = image/picture) memory or the photographic memory are amazing phenomena. Some people can look at a text page or a column of figures and reproduce all the words and figures correctly. The regions in the brain in which the iconic memory manifests itself, are unknown. Maybe it is even the retina or parts of the optic nerve. One could speculate that the brain made room ca. 10,000 years ago for the reading and writing skills.

Different forms of memory

A large part of our learning consists of learning motor activities such as grasping. In their first month the babies flail their arms uncontrolled when they want an object. Already in their fifth month a purposeful grasping movement has developed. The same is true later for learning to walk and to talk which requires exactly coordinated fine motor manipulations of lips, tongue and other elements in the nasopharyngeal zone.

The philosopher Maine de Biran differentiated three forms of memory: the representative memory, which remembers ideas and events, the mechanical memory, which recalls habits and dexterity and the sensitive memory neurobiology greatly, although did not allocate these forms of memory to regions in the brain. Towards the end of the 19th century, the philosopher and psychologist W. James reduced this number to two: habits and conscious memory. The habits consist of walking, writing, singing, etc., that is routine activities we learn without thinking about them. Conscious memory, on the other hand, needs, according to his perception, the build up of associations from individual stored parts. James was also the first scientist who distinguished between long-term and short-term memory.

Around 1880 the psychologist H. Ebbinghaus (1850-1909) examined the language memory and conducted systematic experiments about learn – and memory procedures. He was also interested in the speed of forgetting. The law of the so called Ebbinghaus curves says: at only low increase, the needed learning time increases significantly. Ebbinghaus is seen as one of the exponents of the so called Behaviourists school of objective psychology. (cf. thesis: ch. 4.1)

In the years 1960 – 1970 experimental proof increased of the existence of different forms of memory which are, furthermore, located in different regions of the brain. In particular, patients ho had part of their brain operatively removed to palliate epileptic fits “contributed” to these findings. *When surveying the literature, it is still noticeable that a considerable part of it is concerned with speech impediments (aphasia) (JH)*. Patients with cerebral damages as well as modern imaging technology such as the computer tomography scanner (CT scanner) have led to a new and universally accepted understanding of the localisation of memory activity. There are different forms of memory which have their focal points in the architecture of the brain, but memory is an achievement of the whole brain.

(Gassen, 2008, pp. 58-59)

Some targets for memory models

This introductory article to the Journal of Memory and Language special issue on memory models discusses the progress made in the field of memory modeling during the last few decades in terms of a number of previously suggested criteria, using the articles in this issue as examples. There has been considerable progress, both at a technical level (e.g., concerning model comparison and model analysis techniques) and at a psychological level (as evidenced by the increasingly tight interplay between theory and data on human memory). The article concludes by proposing a few generic targets for future modeling work.
(Lewandowsky & Heit, 2006)

Working Memory (WM)

(cf. thesis, p. 35)

In the working memory we store information for a short period of time, usually not more than a few seconds. Miller (1956) states that the working memory can only process seven units of information +/-2; the magical number 7. (It should be noted that Ebbinghaus had already arrived at this possibility much earlier). On this subject, Miller is probably the most quoted psychologist. However, he explained himself (1989) that he was not all that serious on this subject (Cowan, Morey, Chen, Gilchrist, & Saults, 2008). His mentioning of the “Seven Pillars of Wisdom” and other examples of this kind, should have given his followers a clue. But Broadbent (1975) and Cowan et al. (2008) are indeed of the opinion that there are fixed capacity limits. See also Cowan & Morey (2007) and Saults & Cowan (2007).

The WM can be tricked into storing more information units if these units are presented in groups (chunks). However, Cowan (2001) has shown that the tested capacity of the WM can have something to do with the test method itself. But mainly linked with the WM is the psychologist A. Baddeley. He defined three parts of this kind of memory: the *visualspatial sketch pad* for storing visual information, the *phonological loop* for storing verbal information and one central part, coordinating the other two, the *central executive*. He also suggested the existence of an *episodic buffer* for episodic information (Baddeley, 1997, 2003; Baddeley & Hitch, 1974).

It seems that the WM, unlike the LTM, contains neurons that are continually at work (active)(Funahashi, Bruce, & Goldmann-Rakic, 1989; Fuster, 1995a, 1995b; Fuster & Alexander, 1971). Memory derives from the changes in the synapses in a neural circuit: short-term memory from functional changes and long-term memory from structural ones (Kandel, 2006, p. 221)

WM has been described as “denoting short-term memory tasks that require some kind of additional manipulation, containing some sort of distraction, or demand a degree of simultaneous performance, and have a high correlation with gF (fluid intelligence).

It has been suggested that there is a second class of memory task, which is called *short-term memory*. This involves merely the retention and repetition of information, which has a low correlation with complex mental abilities and gF. (Klingberg, 2009, pp. 43, op cit.) Some use the term “working memory” when they describe its working in the human brain and not in animals. The available evidence so far, including biological, points to the importance of the working memory, concerning all aspects of language. Some of the ideas of theories of memory, such as the phonological loop, have been confirmed by the neurosciences. (cf. Library)

(Kandle’s account of his involvement in memory and brain research which led to the Nobel Prize makes fascinating reading.)

Besides, the WM seems to be the favourite subject for researchers. As far as I can see, research on the WM is far more plentiful than that on LTM.

Just a thought: neuroscientists always concentrate on activated areas of the brain, never on those that are not activated – or so it seems. It could well be that there is important information in the non-activated cells. There are precedents for this. It took human sciences quite a long while before they discovered that we are not entirely rational and that we have a sub conscience. When our ancestors looked to the sky, they saw only the lighted stars and nothing in between, the void. We know now that this "void" is not void at all. When we look at our cities from above at night, we see maps of light with dark places in between. This does not, however, mean that nothing happens there.

Language and short term memory are often mentioned in the same breath, at least in our disciplines. Chain et al (2003) There are many theories which link the two closely together. Chain et al (2003) suggest that such this has to be re-examined. They found that "Importantly, this alternative account suggests links between working memory and language that are not afforded by currently prevailing interpretations."

Two distinct origins of long-term learning effects in verbal short-term memory

Verbal short-term memory (STM) is highly sensitive to learning effects: digit sequences or nonword sequences which have been rendered more familiar via repeated exposure are recalled more accurately. In this study we show that sublist-level, incidental learning of item co-occurrence regularities affects immediate serial recall of words and nonwords, but not digits. In contrast, list-level chunk learning affects serial recall of digits. In a first series of experiments, participants heard a continuous sequence of digits in which the co-occurrence of digits was governed by an artificial grammar. In a subsequent STM test participants recalled lists that were legal or illegal according to the rules of the artificial grammar. No advantage for legal lists over illegal lists was observed. A second series of experiments

used the same incidental learning procedure with nonwords or non-digit words. An advantage for legal versus illegal list recall was observed. A final experiment used an incidental learning task repeating whole lists of digits; this led to a substantial recall advantage for legal versus illegal digit lists. These data show that serial recall of non-digit words is supported by sublist-level probabilistic knowledge, whereas serial recall of digits is only supported by incidental learning of whole lists.
(Majerus, Martinez Perez, & Oberauer, 2012)

Long Term Memory (LTM)

(cf. thesis, p. 39)

Differently from the WM, information is stored in the LTM by permanently reinforced neuronal connections. This process takes (much) longer and requires, among other things, the production of new proteins which are needed to grow new synaptic connections (also Kandel, 2006, p. 212/256). LTM has not the capacity limitations of the WM. There is the *isodic memory* for events and the *semantic memory* for facts. (Klingberg, 2009, pp. 35-36; 46)

But how does information move from short-term memory to long-term memory? It is rather complicated and I would suggest you read Kandel, but here is an example: “In retrospect, our work on long-term sensitization and the discovery of the prionlike mechanism brought to the forefront three new principles that relate not only to *Aplysia* but to memory storage in all animals, including people. First, activating long-term memory requires the switching on of genes. Second, there is biological constraint on what experiences get stored in memory. To switch on the genes for long-term memory, CREB-1 proteins must be activated and CREB-2 proteins, which suppress the memory enhancing genes, must be inactivated. Since people do not remember everything they have learned-nor would anyone want to-it is clear that the genes that encode suppressor proteins set a high threshold for converting short-term to long-term memory. It is for this reason that we remember only certain events and experiences for the long run. Most things we simply forget. Removing that biological constraint triggers the switch to long-term memory. The genes activated by CREB-1 are required for new synaptic growth. The fact that genes must be switched on to form long-term memory shows clearly that genes are not simply determinants of behaviour but are also responsive to environmental stimulation, such as learning.

Finally, the growth and maintenance of new synaptic terminals makes memory persist. Thus, if you remember anything of this book, it will be because your brain is slightly different after you have finished reading it. This ability to grow new synaptic connections as a result of experience appears to have been conserved throughout evolution. As an example, in people, as in simpler animals, the cortical maps of the body surface are subject to constant modification in response to changing input from sensory pathways." (Kandel, 2006, pp. 275-276)

Forgetting

We view the facility of the memory system as twofold: Memory and Forgetting. One cannot have one without the other. This is intended by evolution. As we have seen, learning takes place through anatomical changes in the brain, the strengthening and forming of synaptic connections. If these connections are not constantly "exercised" by stimuli/recall/cues, they weaken and will eventually disappear. Thus total loss of that particular memory would occur. Fortunately, the memory system has a built in safety valve. Of the various synaptic connections a small number will remain, albeit in an atrophic state. They are dormant, to use a metaphor. Only when strong stimuli reach them, they will again begin to grow. Two examples: Face recognition. When I meet a perfect stranger and can't place here, she will tell me that we were at school together, she lived in the neighbourhood and at a school trip I poured cocoa over her. This is enough to rejuvenate the relevant synaptic connections and memory of her will slowly come back. When I have “totally” forgotten a word, seeing it again several times with the translation and/or in context, (re-noticing) will speed up the strengthening of the synaptic connections and it will be locked in memory a little bit firmer. What it really amounts to is repetition. As with all memory tasks, repetition is vital in vocabulary learning, no matter what method is used. (Kandel, 2006 op cit), with my additions.

In this context, it should not be forgotten, that the brain is not only occupied with language. It should therefore not come as a surprise that among the many SLA acquisition theories there is one that treats SLA as a skill like any other. This theory assumes that SLA acquisition happens in two stages, involving STM and LTM. As we have seen, STM has limited capacity and in order to store something there a little bit longer needs conscious effort and information is stored one after the other (serial). LTM storage (with for all intents and purposes, unlimited capacity) follows. LTM takes in information not in sequence but parallel. Storage in LTM cannot be affected by conscious effort – it needs the detour through the STM. This is believed to be happening by repetition of the visual and phonological information. For this a certain amount of direct attention has be present. The STM also holds information derived from the LTM which keeps its neurons permanently activated. (J. R. Anderson, 1995; Ellis, 2000; Takac, 2008) There are papers which examine this in the context of vocabulary learning (Hulme, Maughan, & Brown, 1991; Papagno, Valentine, & Baddeley, 1991)

What memory is for?

Let’s start from scratch in thinking about what memory is for, and consequently, how it works. Suppose that memory and conceptualization work in the service of perception and action.

In this case, conceptualization is the encoding of patterns of possible physical interaction with a three-dimensional world. These patterns are constrained by the structure of the environment, the structure of our bodies, and memory. Thus, how we perceive and conceive of the environment is determined by the types of bodies we have. Such a memory would not have associations. Instead, how concepts become related (and what it means to be related) is determined by how separate patterns of actions can be combined given the constraints of our bodies. I call this combination “mesh.” To avoid hallucination, conceptualization would normally be driven by the environment, and patterns of action from memory would play a supporting, but automatic, role. A significant human skill is learning to suppress the overriding contribution of the environment to conceptualization, thereby allowing memory to guide conceptualization. The effort used in suppressing input from the environment pays off by allowing prediction, recollective memory, and language comprehension. The author reviews theoretical work in cognitive science and empirical work in memory and language comprehension that suggest that it may be possible to investigate connections between topics as disparate as infantile amnesia and mental-model theory.
(Glenberg, 1997)

Learning second language vocabulary: Neural dissociation of situation-based learning and text-based learning.

Jeong et al (2010) examined learners of a second language who used different “modes”, text-based learning and situation based learning. They found that their experiment indicated that brain uses for the L2 different regions, if different learning modes were used.
This is all very interesting but I would want to know if that has any effect on the “quality” of learning.

Second-language learning and changes in the brain.

Osterhouta et al (2008) show how modern brain based method can be used to determine if the brain changes with the learning of L2 and how. They indeed found changes (basically, Kandel had already established that learning changes the brain). They also found that the brain's electrical activity and its structure. It seems that these changes occur immediately with the beginning of the learning.

"According to Pulvermüller, (1999) words are represented in the brain by cell assemblies Hebb (1949) distributed over different areas, depending on semantic properties of the word. For example, a word with strong visual associations will be represented by a cell assembly involving neurons in the visual cortex, while a word suggesting action will selectively activate neurons in the motor areas. This is not very surprising but worth confirming. They carried out two experiments which confirmed this "partially".

Systemic functional linguistics (SFL) is based on the facts that all language can only exist in context and the speakers are not restricted in their choice of words. Below these assumptions are several "metafunctons", one of which is the ideational function (ideation base). For more information: (Butt, Fahey, Feez, Spinks, & Yallop, 2000; Halliday, 1994). Melrose (2005) claims that as far as neural processing is concerned, there does not exist any research on the basis of SFL. He rectifies the situation (you will encounter the mirror system again) by concentrating on the metafunction as mentioned above and finds that SFL is supported by neurological evidence.

It can easily be understood that there is a lively debate whether phrasal verbs are one piece of vocabulary or more. The debate is so far undecided. Cappelle et al (2010) have now used the neuroscienes to settle this matter. They found that their research “provides neurophysiological support that a congruent verb–particle sequence is not assembled syntactically but rather accessed as a single lexical chunk”.

Retrieval failure contributes to gist-based false recognition

People often falsely recognize items that are similar to previously encountered items. This robust memory error is referred to as gist-based false recognition. A widely held view is that this error occurs because the details fade rapidly from our memory. Contrary to this view, an initial experiment revealed that, following the same encoding conditions that produce high rates of gist-based false recognition, participants overwhelmingly chose the correct target rather than its related foil when given the option to do so. A second experiment showed that this result is due to increased access to stored details provided by reinstatement of the originally encoded photograph, rather than to increased attention to the details. Collectively, these results suggest that details needed for accurate recognition are, to a large extent, still stored in memory and that a critical factor determining whether false recognition will occur is whether these details can be accessed during retrieval.
(Guerin, Robbins, Gilmore, & Schacter, 2012)

Knowledge affords distinctive processing in memory

The effect of knowledge on memory generally is processing. However, both conceptual and empirical reasons exist to suspect that the organizational account is incomplete. Recently a revised version of that account has been proposed under the rubric of distinctiveness theory. (Rawson & Van Overschelde, 2008) The goal of the experiments reported here was to extend the distinctiveness theory to the effect of knowledge on event-based as well as item-based memory. High and low knowledge individuals were shown two lists of items, each containing domain relevant items and control items. Various orienting tasks

were performed across the experiments, which in conjunction with type of material and level of knowledge defined distinctive processing. The tests required recognition of items from the second of the two lists in the presence of lures drawn from the first list as well as novel items. For domain relevant material, hits and false alarms were a direct function of knowledge, the rates of which were predicted successfully by the distinctiveness theory. Most current theories attribute the effect of knowledge on memory to organizational processing. The results of these experiments illustrate the importance of item-specific processing to supplement organizational processing in order to adequately explain skilled memory.
(Hunt & Rawson, 2011)

Gesturing makes memories that last

When people are asked to perform actions, they remember those actions better than if they are asked to talk about the same actions. But when people talk, they often gesture with their hands, thus adding an action component to talking. The question we asked in this study was whether producing gesture along with speech makes the information encoded in that speech more memorable than it would have been without gesture. The authors found that gesturing during encoding led to better recall, even when the amount of speech produced during encoding was controlled. Gesturing during encoding improved recall whether the speaker chose to gesture spontaneously or was instructed to gesture. Thus, gesturing during encoding seems to function like action in facilitating memory.
(Wagner Cook, KuangYi Yip, & Goldin-Meadow, 2010)

‘‘I’ll remember this!” Effects of emotionality on memory predictions versus memory performance

Emotionality is a key component of subjective experience that influences memory. We tested how the emotionality of words affects memory monitoring, specifically, judgments of learning, in both cued recall and free recall paradigms. In both tasks, people predicted that positive and negative emotional words would be recalled better than neutral words. That prediction was valid for free recall of positive, negative, and neutral words, but invalid for cued recall of negative word pairs compared to neutral and positive pairs; only positive emotional pairs showed enhanced recall relative to neutral pairs. Consequently, people exhibited extreme overconfidence for cued recall of negative word pairs on the first study-test trial. We demonstrate that emotionality does not globally enhance memory, but rather has specific effects depending on the valence and task. Results are discussed in terms of this complex relationship between emotionality and memory performance and the subsequent variations in diagnosticity of emotionality as a cue for memory monitoring.
(Zimmerman & Kelley, 2010)

Functional memory versus reproductive memory

A functional theory of memory has already been developed as part of a general functional theory of cognition. The traditional conception of memory as “reproductive” touches on only a minor function. The primary function of memory is in constructing values for goal-directedness of everyday thought and action. This functional approach to memory rests on a solid empirical foundation. The function of memory is to bring past experience to bear on present action. This function is manifest in our everyday judgements and decisions of family and work and in our personal mental life. Memory in everyday life may just be called *functional memory*. Functional memory is barely

recognised in the traditional perspective of *reproductive* memory.
(N. H. Anderson, 1997)

We as teachers concentrate on the *reproductive* memory, i. e. memorization. Glenberg (1997) and Anderson (1997), among others, remind us that memory is more than that. They complain that “contemporary psychology of memory has been dominated by the study of memorization”. Very true.
JH

Anderson, J. R. (1995). *Learning and Memory: An Integrated Approach.* New York: Wiley.

Anderson, N. H. (1997). Functional memory versus reproductive memory. *Behavioral and Brain Sciences, 20*(1), 19-.

Baddeley, A. D. (1997). *Human Memory-Theory and Practice*. Hove (UK): Psychology Press Publishers.

Baddeley, A. D. (2003). Working Memory: Loking Back and Looking Forward. *Nature Reviews Neuroscience*(4), 829-839.

Baddeley, A. D., & Hitch, G. J. (1974). *Working memory* (Vol. 8). Hove (UK): L.E.A.

Broadbent, D. E. (1975). The magic number seven after fifteen years. In A. Kennedy & A. Wilkes (Eds.), *Studies in long-term memory* (pp. 3-18). Oxford: Wiley & Sons.

Butt, D., Fahey, R., Feez, S., Spinks, S., & Yallop, C. (2000). *Using Functional Grammar* (2nd ed.). Sydney: National Centre for English Language Teaching and Research, Macquarie University.

Cappelle, B., Shtyrov, Y., & Pulvermüller, F. (2010). Heating up or cooling up the brain? MEG evidence that phrasal verbs are lexical units. *Journal of Neurolinguistics*(115), 189-201.

Chain, J. M., Ravizza, S. M., & Fiez, J. A. (2003). Using neuroimaging to evaluate models of working memory and their implications for language processing. *Journal of Neurolinguistics*(16), 315-339.

Cowan, N. (2001). The Magical Number 4 in Short Term Memory: A Reconsideration of Mental Storage Capacity. *Behavioral and Brain Science*(24), 87-185.

Cowan, N., & Morey, C. C. (2007). How can dual-task working memory retention limits be investigated? *Psychological Science, 18*, 686-688.

Cowan, N., Morey, C. C., Chen, Z., Gilchrist, A. L., & Saults, J. S. (2008). Theory and measurement of working memory capacity limits. . *The Psychology of Learning and Motivation, 49*, 49-104.

Ellis, R. (2000). *Instructed Second Language Acquisition*. Cambridge USA: Blackwell.

Funahashi, S., Bruce, C. J., & Goldmann-Rakic, P. S. (1989). Mnemonic coding of visual space in the monkey's dorsolateral prefrontal cortex. . *Journal of Neuropsychology, 61*, 331-349.

Fuster, J.M. (1995a). *Memory in the cerebral cortex*. Cambridge, MA: MIT Press.

Fuster, J.M. (1995b). Memry in the cortex of the primate. . *Biological Research, 28*, 59-72.

Fuster, J.M., & Alexander, G. E. (1971). Neuron Activity Related to Short Term Memory. *Science*(173), 652-654.

Gassen, H. G. (2008). *Das Gehirn*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Glenberg, A. M. . (1997). What memory is for. . *Behavioral and Brain Sciences, 20*, 1-55.
Guerin, S. SA. , Robbins, C. A. , Gilmore, A. W. , & Schacter, D. L. (2012). Retrieval failure contributes to gist-based false recognition. *Journal of Memory and Language, 66*, 68-78.
Halliday, M. A. K. (1994). *An introduction to functional grammar* (2nd ed.). London: Edward Arnold.
Hebb, D. O. (1949). *The Organisation of Behaviour.* New York: Basic Books.
Hulme, C., Maughan, S., & Brown, G. D. A. (1991). Memory for familiar and unfamiliar words: evidence for a long-term memory contribution to short-term memory span. *Journal of Memory and Language, 30*, 685-701.
Hunt, R. R. , & Rawson, K. A. (2011). Knowledge affords distinctive processing in memory. *Journal of Memory and Language, 65*, 390-405.
Jeong, Hyeonjeong, Sugiura, Motoaki, Sassa, Yuko, Wakusawa, Keisuke, Horie, Kaoru, Sato, Shigeru, & Kawashima, Ryuta. (2010). Learning second language vocabulary: Neural dissociation of situation-based learning and text-based learning. *NeuroImage, 50*, 802-809.
Kandel, E. R. (2006). *IN SEARCH OF MEMORY*. Ney York: W. W. Norton & Company.
Klingberg, T. (2009). *The Overflowing Brain*. Oxford: OUP.
Lewandowsky, S. , & Heit, E. (2006). Some targets for memory models. *Journal of Memory and Language, 55*, 441-446.
Majerus, S., Martinez Perez, T. , & Oberauer, K. (2012). Two distinct origins of long-term learning effects in verbal short-term memory. . *Journal of Memory and Language, 66*, 38-51.
Melrose, A. (2005). How a neurological account of language can be reconciled with a linguist's account of language: The case of systemic-functional linguistics. *Journal of Neurolinguistics*(18), 401-421.
Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81-97.
Miller, G. A. (1989). George A. Miller. In L. Gardner (Ed.), *A history in psychology in autobiography* (Vol. 8, pp. 391-418). Stanford, CA: Stanford University Press.
Osterhouta, L. , Poliakov, A., Inoue, K., McLaughlin, J., Valentine, G., Pitkanen, I., . . . Hirschensohn, J. (2008). Second-language learning and changes in the brain. *Journal of Neurolinguistics*(21), 509-521.
Papagno, C., Valentine, T., & Baddeley, A. D. (1991). Phonological short-term memory and foreign language vocabulary learning. *Journal of Memory and Language, 30*, 331-347.
Pulvermüller, F. (1999). Words in the brain's language. *Behavioural and Brain Sciences, 22*, 253-336.
Rawson, K. A. , & Van Overschelde, J. P. (2008). How does knowledge promote memory? The distinctiveness theory of skilled memory. . *Journal of Memory and Language, 58*, 646-668.
Saults, J. S., & Cowan, N. (2007). A central capacity limit to the simultaneous storage of visual and auditory arrays in working memory. *Journal of Experimental Psychology: General, 136*, 663-684.
Takac, V. P. (2008). *Vocabulary Learning Strategies and Foreign Language Acquisition*. Clevedon.
Wagner Cook, S, KuangYi Yip, T. , & Goldin-Meadow, S. (2010). Gesturing makes memories that last. *Journal of Memory and Language, 63*, 465-475.
Zimmerman, C. A., & Kelley, C. M. (2010). ''I'll remember this!'' Effects of emotionality on memory predictions versus memory performance. . *Journal of Memory and Language, 62*, 240-253.