**Comment on Y. Wang, D. Liui, Y. Wang, "Discovering the capacity of human memory" *Brain and Mind* 4 (2003) 189–198**

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Without thorough knowledge about the human brain and memory, it is difficult to make a good estimation about the size of the human long term data storage capacity. Although more knowledge is gained over the years due to extensive research and more sophisticated techniques, still much is unknown about the functioning and the capacity of human long term storage. However, it has become clear that the human memory is associative and that the relations between neurons -their mutual connections by synapses- are very important in memorization. But how long term information is stored exactly is yet unknown. Still, one can attempt to determine an upper boundary on the total capacity of the brains long term storage. Different methods have been published, but most of these still suffer from the lack of knowledge about the "memory hardware" in the human brain. Landauer has used a method to determine the capacity of human memory which circumvents this problem by measuring the actual functional data storage capability of human memory directly [Landauer1986]. In his study, the human data storage capability was found to be a mere 2 bits per second. Using this value, one can estimate that the maximum amount of data the human brain can store during a life time lies somewhere between 1-10 Gbit.

Of course attempts should be made to estimate the capacity based on what we know about the brains functionality. An obvious first attempt is to determine an upper limit based on the number of connections between neurons in the brain ($10^{13}$). The object-attribute-relation (OAR) model used by Wang *et al* is attempt along this line [Wang2003a, Wang2003b]. Much attention is given in this method to the relational and associative character of the human memory, because that is one of characteristics of the human brain of which are quite certain. But surprisingly, the authors are less critical on the value of $10^{8432}$ bits they obtain. When one realizes that the entire universe contains about $10^{120}$ atoms, the this value is far beyond every imagination. How can that amount of bits possibly be 'written' somehow in the human memory? An analysis of this method seems to be necessary.

The OAR model is based on the number of *possible* connections. Therefore, one bit equals not only a connection, but also a *possible* connections. But how can a possible connection contain information? It can be compared for example to a 4 bits computer word: 1 0 1 1. There is no doubt this is a 4 bits piece of information. But using the argumentation of the OAR model, this four bits word becomes a 32 bits piece of information, because this is the number of *possible* combinations for a 4 bits computer word. It is fundamentally wrong to represent a *possible* neural connection by one bit, which explains the unrealistically large capacity.

When only the number of existing neural connections are determined and we assume that one bit equals one connection, we can count the number of synapses, resulting in $10^{13}$ to $10^{15}$ bits. This value still is $10^4$ to $10^6$ times larger than the value estimated by Landauer. It is interesting to see that apparently a very small fraction of the human brain is actually used for data storage. This is exactly opposite to modern computer architecture, and it is difficult not to admire the elegance of the brains software.

[Landauer1986] "How Much Do People Remember? Some Estimates of the Quantity of Learned Information in Long-term Memory", in Cognitive Science 10, 477-493, 1986
[Wang2003a] Y. Wang, D. Liui, Y. Wang, "Discovering the capacity of human memory" *Brain and Mind* 4 (2003) 189–198
[Wang2003b] Y Wang, D. Liu "On information and Knowledge Representation in the Brain" *Proceedings of the second IEEE international conference on cognitive informatics* (2003) p 26-31