Quantum Dynamical Psychology

Qubits Underlie Gifted Savants

John Robert Burger

Abstract

Qubits restricted to vector-up or vector-down may be realized with neurons that are applied in parallel to explain the gifted behaviors of savants. This paper synthesizes qubit systems that are electrically and procedurally reversible, and that could support quick learning, or memorization and calculational achievement as demonstrated by gifted savants.

Key Words: neural qubits, qubit Memory, qubit Arithmetic, reversible systems, savants

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Introduction

The root causes of savant syndrome are not the focus here except to say it is often associated with autism and occasionally with head injuries. What is important here is that savants sometimes have unusual mental abilities far beyond the average person. Often their abilities are in a very narrow area so are termed *splinter skills*. One wonders how they do it, and what the lesson is for the rest of us.

Some savants have photographic memories and are able to recall vast amounts of information after seeing it only once. For example, a musical prodigy might play a complex piano piece after hearing it only once, thus displaying superior memory coupled with physical ability. Autistic artists draw complex accurate scenes without erasing. Savant talkers excel at foreign languages with no trace of an accent. Others might recite an entire book after reading it only once. Savants known as "mental calculators" occasionally excel at rapid multiplications, divisions, roots, powers, prime numbers recognition and other calculating skills.

Many savants demonstrate calendar skills. They enjoy asking people for the date of their birth, and then telling them on which day of the week they were born. Brief case histories of a few modern day savants are provided in Appendix 1. The most common explanation given for their abilities is that savants have apparent increased ability to remember. While this possibility can account for some savant skills, it fails to explain others.

Savants have demonstrated more than ordinary memorization of answers. Merely memorizing the products of two arbitrary numbers, each between 1 and 1,000,000 requires a table with roughly one trillion (10^{12}) entries, depending on organization, which exceeds estimates of neural count. A gifted savant is able to accept large numbers for several categories of operations, multiplications, square and cube roots, primes and so on, so pure memory would have to be astronomical and beyond brain capacity. If follows that more is happening than ordinary memorization, at least in the case of mental calculators.

Another proposed explanation is that savant skills are due to the development of

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super-intense concentration levels that normal people are unable to achieve. The underlying idea is that savants are less prone to distraction, being that they are only interested in extremely narrow areas. Again, this theory can account for some but not all savants.

A common hypothesis is that a savant brain is physically no different from anyone else's, but that they are very focused on extremely specialized achievements, a view exemplified by Howe and others (Howe, 1989). But none of the above theories mention how brains might work physically. In contrast, this paper addresses savant abilities by considering possible developments of brain structure to explain their demonstrated photographic memory and calculational brilliance as exemplified in the appendix.

Savant brains are different but still must be grounded in physical reality. In general, there is no reason to believe that the information processing capabilities of savants obey anything other than the laws of physics. Physics and physical metaphors can be quite useful in practice. For example, an understanding of psychopathology has been increased by using concepts from information theory (Germine, 1993). Similarly, knowledge of electrical and computer system design sheds a new light on efforts to synthesize the underlying circuits that explain savant behavior. Synthesis in this context means that a relatively small number of input-output behaviors are used to guide the creation of neural architecture and neural circuits.

Synthesis is normal within engineering but not necessarily in academia. A synthesis effort must be evaluated by the utility of its result, not by the length of its list of references, since presumably new designs are original and unpublished. Synthesis is not fundamentally experimental because for brains, like computers, usually only the inputs and outputs are specified. They have no meaning experimentally until an artificial realization becomes available. The goal is to develop a system such that inputs and outputs match known behaviors, in this case, savant memorizing and calculating abilities. Inputs and outputs are relatively simple compared to what is inside, which is what needs to be synthesized.

An analogy is the microprocessor. The microprocessor is a synthesized device with a profound and revolutionary effect on science. The first microprocessors were not created from academic publications, nor did they particularly benefit from reams of experimental data. Rather they were synthesized (or designed) by designers to achieve a relatively simple list of input-output functions.[2] Synthesis is the very first step in a process of fabrication and testing. Likewise, this paper synthesizes neural qubits as a very first step before artificial brain generation, experiment design and subsequent testing.

The Concept of a Neural Qubit

It is reasonably estimated that the conscious mind is capable of processing only about 40 micro operations per second, about the frequency of a gamma brain wave. This is too slow to support savant processing. Limited rates for conscious processing suggest that serial algorithms are unlikely. Parallel algorithms in the subconscious or semiconscious are more likely. Thus the author was led to consider the possibilities of quantum parallelism as exhibited by qubits.

The underlying hypothesis is that instead of conventional memory such as flip flops, the brain operates like a complex state machine involving specialized qubits that can be either zero or one. They are indeed qubits because they are electrically reversible and they support reversible programming. It is unknown exactly how neurons form into qubits, but a possible circuit is provided below.

The qubit concept works well for brains, especially in explaining savant brains, because qubits seem to explain photographic memory and amazing calculational abilities. Unconstrained qubits may have a vector pointing in any direction in three dimensions. The qubits proposed below, although modeled to be adiabatic, like the qubits of quantum theory, are classical in an important way: The qubits used below

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[2] In November, 1971, a company called Intel publicly introduced the world's first single chip microprocessor, the Intel 4004 (U.S. Patent #3,821,715)

are vectors in one-dimensional space that point up or down. Qubit entanglement is not considered here. Also, this paper does not go into the conditions for conscious awareness of a computed result from the subconscious brain.

Neural qubits as used below are in fact controlled toggle switches, this being a special type of memory. Controlled toggle switches, by the way, have transistor realizations that are also electrically reversible and supportive of reversible programming (Burger, 2009). Controlled toggling permits reversible algorithms for parallel arithmetic, such as multiplications and divisions. Controlled toggle switches may display either a one or a zero (but not both at the same time like unconstrained qubits).

Figure 1 is a possible neural implementation of a reversible controlled toggle circuit. One or zero is stored in the latch comprised of Inverters 1 and 2. A toggle signal (To) initiates a toggle as follows: The inverters are disabled by gradually reducing V_1. The original output of the inverters V_{tog} is held in C_1 and C_2. Waveforms V_2 and V_3 are next cycled to their complementary values and back again to apply a toggled signal to the input of inverter 1. The two inverters are gradually, and thus reversibly enabled again via V_1 and latch a new state. Details that formally prove electrical reversibility are available elsewhere (Burger, 2009).

Neurons are of course able to implement logic operations of their own, although possibly in a completely different way. However, the gradual changes analogous to the controlling voltages (V_1, V_2 and V_3) are naturally achieved in neurons by relatively slow action potentials.

Ideally qubits are reversible and therefore may operate indefinitely without excessive power dissipation. They come to mind because a brain also avoids excessive power dissipation. There are no noticeable large releases of heat during a savant's (or any else's) mental activity as anyone may observe for his or herself, no conscious effort, no perspiration, no increases in heart rate and so on (Discovery Channel, Dec 9, 2010).

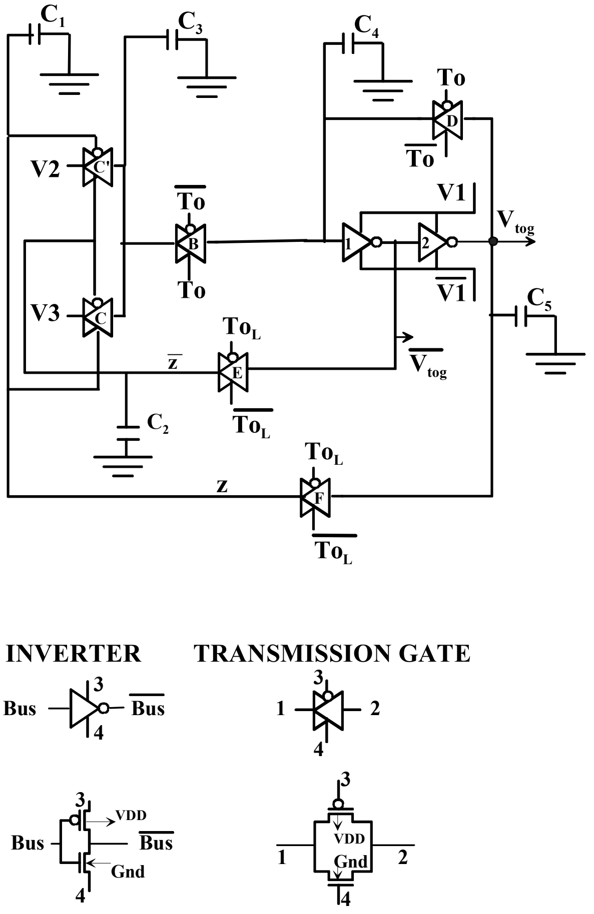

Figure 1. Circuit model of a qubit toggle circuit.

For any human, savant or not, measurements indicate that a fixed number of calories are dissipated irregardless of mental activity. For instance, a 180 lb person sleeping uses about 75 C/hr while a person reading uses merely 86 C/hr, and insignificant increase easily attributed to eyes and such random motions[3]. In contrast, running uses a massive 1102 C/hr (Healthstatus, Dec 9, 2010).

Qubits, including neural qubits, by definition, are physically and thus electrically reversible. Thus it is implied that neural action potentials are adiabatic, meaning that very little energy is lost in the resistance of dendrites or axons during brain signaling. A reader is warned, however, that current theories in physiology teach that neurons require considerable energy for neural action potentials plus another

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[3] 75 C/hr (or kcal/hr) equals about 87 Watts or joules/sec for the whole body while sleeping. Approximately 10 to 20 % of this is consumed by the brain, or about 9 to 18 W, assumed for normal neural maintenance.

substantial energy allotment for biological maintenance. This "wasteful" hypothesis enjoys general influence but is based on indirect evidence not generally accepted (Attwell and Laughlin, 2001). Reversible qubits designed with neurons as in this paper explain savants, but the reversibility of a neuron is speculative and based only on indirect evidence (Burger, 2010a).

1. Qubits for Calculating

Savant brains are proposed to have many parallel rows or words of qubits. Having many parallel words is suggestive of quantum parallelism. A savant would be unaware of the parallel processing in such a structure.

Reversibility and energy efficiency are major features of ideal qubits. But practical qubits have a fairly large energy overhead since they are often designed with lasers, cryogenics, and electromagnetic fields. It would not be totally surprising if biological qubits also have energy overhead. Even if they do, the model of this paper is still valid because the logical aspects of qubits still apply.

For savants with skills in arithmetic, parallel qubit processing provides an explanation beyond mere memorization. Qubit processing works as follows. A word of memory filled with qubits can be diagrammed as in Fig. 2.

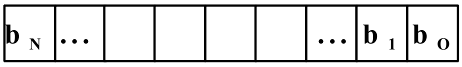

Figure 2. Specialized qubits comprising a word of savant processing memory (b_o is a flag qubit).

Such qubits may interact with each other when commanded to do so. ~~by~~ Signals from deep within long term memory can test a *selected* set of qubits organized as above; if the tested qubits are all true, then the controls will complement one or more other selected qubits within the word. Tested qubits have to be disjoint from the other selected qubits in a word to maintain logical reversibility (and low energy dissipation). Operations like this involve controlled toggling which is logically reversible. This is totally unlike modern computer logic and dynamic memory which has destructive readout and great loss of information, and great heat release.

At this point it is helpful to define a '*wiring*' diagram as used in the field of reversible computing (Pittenger, 1999). A wiring diagram does not involve any wires; rather, a wiring diagram serves to specify a logically reversible computer program. As suggested in Fig. 3, one may imagine that each line in a wiring diagram is related to a qubit position in each of the parallel words of qubit memory with N+1 qubits per word. There may be any number of words, up to L = 2^N, each with different information. Each word is going to follow the instructions given in a wiring diagram.

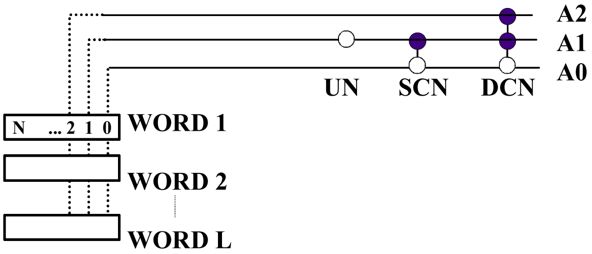

Figure 3. Relationship between wiring diagram and qubit positions

Shown in the figure are the symbols for UN (unconditional NOT), SCN (single controlled NOT) and DCN (double controlled NOT); these and a few other basic qubit instructions can accomplish all necessary arithmetic. Fig. 4 illustrates an unconditional NOT or UN.

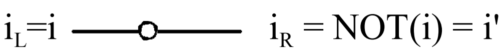

Figure 4. Symbol for Unconditional NOT gate or UN

The logically reversible NOT gate is a special gate such that a signal $i_L = i$ on the left is computed on the right as $i_R = i'$ meaning the NOT of *i*. If *i'* is applied on the right, then *i* is computed on the left; so this gate is logically reversible. The bubble in a wiring diagram is a symbol for the logically reversible NOT gate. Figure 5 illustrates a single controlled NOT, or SCN:

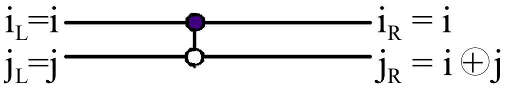

Figure 5. Symbol for single controlled NOT or SCN

The little black dot is a standard symbol for a connection. The $j_L = j$ on the left is complemented only if *i* is true, or in Boolean terms, if $i = 1$. Another way of expressing what is accomplished is:

$$\boldsymbol{j_R = i \oplus j}$$

The symbol ⊕ means XOR of *i* with *j*, that is, XOR(i,j). If *i* is false, then $j_R = j$, and nothing happens. If *i* is true, then $j_R = NOT(j)$, sometimes written as *j'*. Inputs can be applied to the right as readily as to the left, so it is logically reversible. Note that the input *i* is carried through unchanged. This assures that information is not lost (as it would be in irreversible logic).

The idea of controlled NOTs can be extended, creating what may be termed a double controlled NOT or DCN. The symbol for double controlled NOT or DCN appears in Fig 6.

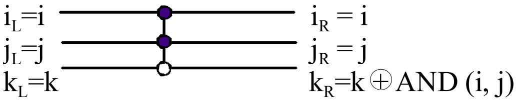

Figure 6. Symbol for double controlled NOT or DCN

The double controlled NOT computes the AND of *i* and *j*, and if the result is true, then $k_R = NOT(k_L)$. The i and j are transmitted without change to ensure reversibility. In Figure 3, for example, if qubits 2, 1, 0 are initialized to 0, 0, 0, the sequence of operations from left to right would give $A_2, A_1, A_0 = 0, 1, 1$ on the right. That is, qubits 2, 1, 0 become 0, 1, 1. Consider adding 1 + 1 as in Fig 7.

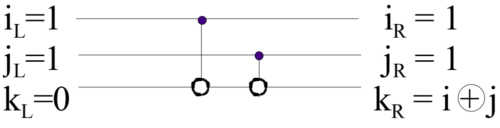

Figure 7. Reversible modulo two addition of 1 + 1

The binary sum of 1 + 1 is 10, that is, the modulo-two sum is zero and the carry is one. Assume that *k* on the left is initialized to $k_L = 0$. The modulo-two sum is computed and appears as k_R on the right. For example, if on the left $i_L = 1$, $j_L = 1$ *and* $k_L = 0$, then on the right is $i_L = 1$, $j_L = 1$ *and* $k_R = i \oplus j = 0$, the correct answer. Note that operations are done in parallel for any number of words in the Fig 3 stack, and with any operands. Using more wires, reversible arithmetic may be extended to arbitrary precision. Such systems can be realized in hardware and possibly with neurons.

Simple applications

To accomplish useful arithmetic in parallel, each word (row of qubits) must be initialized with different numbers. For example, word 1 may contain a given pair of operands; word 2 may contain another pair of operands; and so on to word L with a final pair of operands. Then by applying a given sequence of controlled toggles, parallel arithmetic may be accomplished.

Savants often can identify large prime numbers (Sacks, 1985). Consider how a person might solve the problem of identifying a prime number using parallel processing. Each word in a subconscious stack of words of qubits may be initialized to hold a different low level prime number. Parallel processing could divide a given large number by different low level primes (up to the square root of the number) in a search for exact divisors. One or more of the remainders would be zero for a non prime number; and one would know that a given number is not a prime. But otherwise if all remainders are finite, one would know it must be a prime number. Other methods for prime identification (Caldwell, 2010) are too complex for a savant to reasonably learn and many are unsuitable for a parallel algorithm. Also, the conscious mind is limited to no more than about 40 micro operations per second, thus excluding most serial algorithms.

Many calculating tasks can be visualized as a massively parallel set of operations followed by accumulation somewhere else. For example, when multiplying two large numbers, the multiplicand may be multiplied by each digit of the multiplier in parallel. Then all that remains is to sum the partial products by aptly adding them to an accumulation one at a time to determine the product. Multiplying 678 by 345, for example, can be accomplished by multiplying 678 by 3, while concurrently multiplying 678 by 4, while concurrently multiplying 678 by 5; the product is simply the appropriate sum of the partial products in another subliminal qubit processor.

What is accomplished is generally called vector arithmetic, although operations beyond arithmetic are entirely possible. A vector can be defined as a stack of numbers. A common application is *inner product* in which corresponding elements of two vectors are multiplied, forming a third vector.

As another simple application, imagine a stack of words (as in Fig 3) with a hidden code “1, 1” in given locations here identified as x and y. The word with this code presumably points to other important secret information. Each of many words can be analyzed concurrently using a DCN applied to the x, y locations. To do this, first choose a flag qubit b_0 and initialize it to zero in each word. Then apply the DCN simultaneously to positions x and y in all words. That word that contains the code $x = 1, y = 1, b_0 = 0$ on the left of a wiring diagram is converted to $x = 1, y = 1, b_0 = 1$ on the right of a wiring diagram. In other words, the flag b_0 goes true to identify the hidden word.

This simple idea could be extended to an extremely complex code in an extremely large number of words to identify hidden information. Thus results a solution to the *needle in the haystack* problem using reversible programming.

Calculating pi can be reduced to summing a power series where each term is an operand raised to an integer power, and then divided by that integer. This could be done in a system of subconscious qubit processing, although the wiring diagram is not provided here. As with multiplication, the partial results are accumulated elsewhere in another subliminal qubit processor.

Qubits do not actually move anywhere. They are processed locally. In other words, the processing is data-stationary. This avoids delays and energy loss usually expended when moving data around. In conventional hardware, data-stationary processing is impossible. Data must be moved from mass memory to local memory and then to various registers in a microprocessor; then it must be moved back to local memory and then back to disk memory. This sort of random access reading and writing is the mainstay of desktop computers and dissipates excessive amounts of power as well as time. Generally a bottleneck occurs on a data bus that drastically slows down a conventional computer. Data-stationary computations reduce wasted power and bottlenecks, this being a desirable feature.

Words in subconscious long term memory may contain built-in operands. For example, there may preexist in each qubit word a unique multiplier from 0 to 9 for the parallel calculation of partial products. The multiplicand operand is entered simultaneously into memory words via the usual method that conveys information into long term memory. Parallel multiplication subsequently occurs.

There may be low level prime numbers for the purpose of prime number identification. These basic operands, a different one for each word, may preexist within qubit words.

The above wiring diagrams indicated only a few sequential reversible steps. In general there will be tens if not hundreds of reversible steps involving UN, SCN, DCN and possibly others. Procedures for calculations, as in everyday learning, flow from state machine embedded within subconscious long term memory. Such procedures are assumed previously learned by some method, either by random trials or from books, or from the imitation of others.

2. Qubits in Savant Memorization

Photographic recollection requires memory; calendar skills require memory and perhaps also calculations. But what does it mean to have good memory? Memory space is useless if cues for recall are absent. Memory is related more to access than to volume. Memories of random information are more likely to be recallable if they are connected together somehow by mnemonics, a form of encoding, or alternately by subconscious pointers that automatically produce a next step from previous steps.

What was originally thought to be long term memorization by savants may in fact be described as rapid learning in which hidden pointers are learned from one item to the next (note that this type of learning is unrelated to problem solving). Learning requires rehearsal time. After suitable rehearsal, there is synaptic involvement. Savants may require far less rehearsal than average in order to learn sequences, giving the impression of unusual memory.

Learning of this type is exactly what a state machine implements; it uses hidden pointers that point from one item to the next. *State machine learning* is thought to be responsible for all of the many procedures humans employ unconsciously, including physical and verbal skills. The big advantage of state machine learning is that mental procedures, which range from the mundane to the advanced, do not have to undergo recall and processing through consciousness each time they are used.

An artificial realization of anthropomorphic learning in the form of a qubit state machine appears in Fig 8 (Burger, 2010b). The figure depicts a small scale subcircuit that is capable of stepping from any given memory word to any other memory word within a given region of subconscious long term memory. The *Filters* (Flts) in the figure detect repetition and subsequently hold a signal that enables synaptic growth. Synapses (S_{ij}) are modeled with field effect transistors serving as switches in the figure. Although standard circuit elements are used, neurons could underlie this circuit. There is a possibility that long term potentiation could hold learning connections until synaptic growth occurs, thus implementing the S_{ij} in this learning model. Note that synaptic growth for learning is expected to consume calories over a period of time.

The physical mechanism of objective long term memory is still largely hidden from those who strive to design artificial brains. Interesting strides have been taken for implicit memory (Kandel, 2006) but explicit memory is still a frontier. Synaptic growth for implicit learning takes some time and thus accounts poorly for long term explicit memory that can be formed instantly. Long term potentiation is a possibility but has not yet been designed into a general associative memory system. A valid model for long term explicit memory must be not only instantly writable, but must be content-addressable with circuits for rapidly recalling any stored information into conscious short term memory.

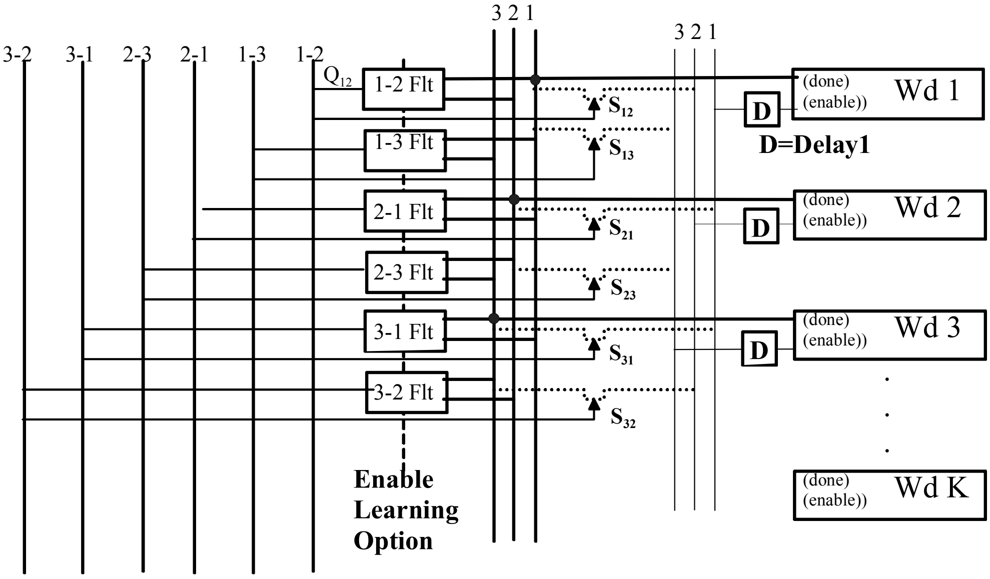

Figure 8. Model for learning in the form of a qubit state machine within subconscious long term memory

Qubits as envisioned here are prime candidates for long term memory elements and at least can serve until better circuits are discovered. The neural qubit concept of Fig. 1 is rather complex since toggling is unnecessary in permanent memory. What is needed is more like programmable read-only memory (PROM). Fig 9 is a representation of a neural memory element (assuming a solid state gate, this is a non reversible version) that could possibly be realized with neurons to be adiabatic and therefore, is a representation of a *minimal* qubit.

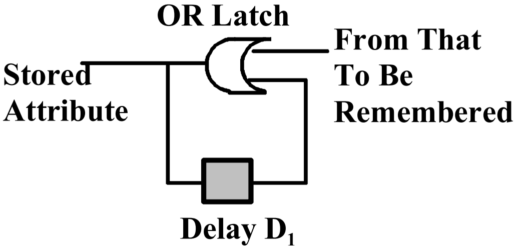

Figure 9. Circuit representation of a minimal neural qubit for permanently holding a single attribute of a memorized image (non reversible version shown)

The circuit is *set* by neural pulses to the input of the OR gate. One may imagine neural pulses that cycle indefinitely through the neural OR gate using very space and very little power. A practical associative memory can be designed with such elements (Burger, 2009). Thus human memory is modeled as a mathematical array of minimal qubits that are randomly located within the brain of any human.

To understand how a savant's sequential learning might differ from ordinary, consider a filter model for rehearsal as in Fig 10. After two signals to the input, the output, assuming proper timing, can be made to go true. There may be additional stages of toggles so that more rehearsals are required before learning occurs. The output of this rehearsal filter goes to a latch as in Fig 9, which holds the learned information so that a synapse can be developed. Savants are proposed to differ in that there are fewer, or perhaps no rehearsal filter stages. This would permit instant learning, and for example, a long recitation without conscious effort.

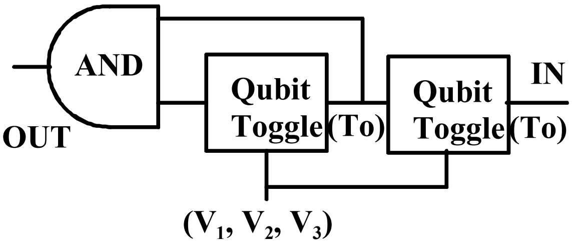

Figure 10. Filter that detects repetitions before learning can occur

To avoid remembering too much, it is necessary to regulate learning using global interneurons through all such qubits, for example, the control signals V_1, V_2 and V_3. These could be activated only by a savant's desire to memorize something interesting. Qubits for instant sequential learning or something biologically analogous could explain what is perceived to be phenomenal memory.

3. Conclusion

Memorization alone will not account for some of the amazing feats performed by savants, nor will paltry processing in consciousness at roughly 40 micro operations per second. However, subconscious parallel processing is a possibility. Such processing may involve many rows of specialized qubits constructed of neurons, all orchestrated in parallel like a vector processor using commands from subconscious long term memory. The system synthesized above is analogous to the superimposed states of a quantum computer. Parallel processing is assumed to be followed by accumulation in another subliminal qubit processor to achieve a final answer.

Qubits in this paper are not the usual three-dimensional vectors of quantum theory. Rather they are one dimensional, restricted to an equivalent of qubit vector-up or qubit vector-down in an attempt to explain the gifted abilities of savants.

These building blocks are properly termed "specialized" qubits because they are physically (and electrically) reversible and therefore energy efficient. Specialized qubits can be constructed with neurons; a possible circuit was shown above. The underlying implication is that neural action potentials are relatively efficient, that is, that very little energy is lost in the resistance of dendrites or axons during brain signaling, and that charge taken from the neural environment is essentially all returned to that environment. This is facilitated by the relatively slow rise and fall times of action potentials in the millisecond range.

Qubits constituting a subliminal vector processor are programmed using procedures from deep within subconscious long term memory. Such procedures flow from subconscious state machines to provide instructions that modify the states of qubits to achieve a calculational result. This may be done without conscious exertion.

Memory is fundamental to savants, but what does memory mean? There is implicit memory which is thought to hold together the processing aspects of the brain as a system and to hold learning. Synaptic growth is a hallmark of implicit memory. On the other hand, explicit memory, be it episodic, procedural or semantic includes short and long term memory but not necessarily synaptic growth. In particular, subconscious explicit long term memory in humans can be formed quite quickly, too quickly for growth, and yet seems to persist indefinitely.

Most important of all, elements of explicit long term memory must fit into a system that provides nearly instantaneous images to short term memory or consciousness. A minimal qubit, working as a simple latch, can do this, and is mentioned here because competing concepts so far have been disappointing in their ability to support an artificial brain system.

Some savants of course are famous for their powers of memory such as remembering books they have read. But pure memory is meaningless unless the connections between the various images of memory are also remembered. The recalling of episodes such as the contents of a book, which is something savants can do, is argued to be a manifestation of quick learning.

Learning in the sense of remembering sequences can be ~~is~~ modeled as synaptic connections within subconscious long term memory. Usually connections are formed rather slowly after much rehearsal as detected by a rehearsal filter. Once learning is in place, synaptic connections define a state machine within subconscious long term associative memory. State machines permit routine movements and recitations without conscious involvement.

Savant learning is proposed to form quickly within subconscious long term memory, this being accomplished because rehearsal filters are either shortened or missing. Rehearsal filters could be cascades of qubits that toggle in a certain order. Eventually they set a minimal qubit or latch. These latches define a particular state machine that is instilled by a process of long term potentiation or subsequent synaptic growth. Once in place, the brain jumps from one word of information to another as fast as the information can be expressed. In this way, without knowing how, a savant remembers amazing sequences studied only once.

The qubit system above is more than a metaphor to a theoretical quantum computer system; it is in fact a machine that could be constructed physically using standard digital and analog components. It is doubtful that a machine would ever be considered gifted, not like a human. But nevertheless this work has proved to be very interesting and is filled with possibilities. By considering reversible neural qubits that are restricted to behave classically as logical ones and zeros, important behaviors, both normal and pathological may be understood.

Appendix 1
Daniel Tammet

Daniel Tammet (1979 -) is classified as an autistic savant who can perform mind-boggling mathematical calculations at breakneck speeds. Unlike many savants, Daniel can communicate what he experiences (Wikipedia, Daniel Tammet, 2010).

Daniel can figure out cube roots quicker than a calculator. Normally pi may be computed with a Machin-like formula. This would be equivalent to

$$\frac{\pi}{4} = 4\arctan(\frac{1}{5}) - \arctan(\frac{1}{239})$$
$$\arctan(x) = x - \frac{x^3}{3} + \frac{x^5}{5} - + \ldots \tag{1}$$

We do not know exactly how, but Daniel has recited pi to 22,514 places. But he cannot drive a car or tell left from right. Daniel describes multiplying 377 by 795. It is a semiconscious effort that allows him to arrive at an answer very fast. He is able to see numbers as shapes, colors and textures. 'When I multiply numbers together, I see two shapes. The image starts to change and evolve, and a third shape emerges. That's the answer. It's mental imagery. It's like math without having to think.'

To Daniel, pi is a particular visual landscape. But he is uncomfortable with too much mental stimulus. In a supermarket "There's too much mental stimulus. I have to look at every shape and texture, every price, and every arrangement of fruit and vegetables; so instead of thinking, 'What cheese do I want this week?' I'm just really uncomfortable." But Daniel says "I do love numbers" and "It isn't only an intellectual or aloof thing that I do. I really feel that there is an emotional attachment, a caring for numbers. I think this is a human thing – in the same way that a poet humanizes a river or a tree through metaphor; my world gives me a sense of numbers as personal. It sounds silly, but numbers are my friends."

Tammet performs multiplications, divisions, roots, powers and prime number recognition. He calculates without apparent effort, but with great concentration, taking roughly two or three seconds for a calculation, far less time that it takes for him to verbalize the resulting answer, and obtains correct answers.

Kim Peek

Another famous gifted savant who could memorize is Kim Peek (1951 -2009). Kim is the inspiration for the character of Raymond played by Dustin Hoffman in the movie Rain Man (Wikipedia, Kim Peek, 2010). Kim Peek was born with a condition in which the nerves connecting the hemispheres are missing.

From an early age Kim was able to memorize large amounts of information and can recall nearly all facts in about 12,000 books he has read. Although he has difficulty with ordinary motor skills, and is below average on general IQ test, he is well above average in specialized subtests. Kim Peek is an example of a person gifted with photographic memory. He reads a book in about an hour and remembers 98% of everything he has read.

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