A Theory of Consciousness Founded on Neurons That Behave Like Qubits
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Abstract
This paper presents a hypothesis that consciousness is a natural result of neurons that become connected recursively, and work synchronously between short and long term memories. Such neurons demonstrate qubit-like properties, each supporting a probabilistic combination of true and false at a given phase. Advantages of qubits include probabilistic modifications of cues for searching associations in long term memory, and controlled toggling for parallel, reversible computations to prioritize multiple recalls and to facilitate mathematical abilities.

Introduction
The author was inspired to this effort years ago by a paperback aimed at capturing the imagination of budding scientists (Berkeley, 1949). In Berkeley’s clever words, “What men know about the way in which a human brain thinks can be put down in a few pages, and what men do not know would fill many libraries.”

This is still true today; the nature of consciousness continues to be a mystery. There seems to be no way to explain physically let alone design such human traits as common sense, truth judgment, understanding, artistic appraisal, and other hallmarks of human intelligence (Penrose, 1989). Recently, visionary pioneers have surveyed the possibility of quantum influences (Tarlaci 2010). No doubt there are important quantum mechanical behaviors within ion channels and within synapses and elsewhere, since ions and their electrons are small enough to be subject to quantum theory (Walker 2000, Burger 17 Sep 2010). An especially interesting hypothesis involves quantum computing within the microtubules of brain cells, proposed to generate consciousness (Hameroff 2007). However, there are objections centering on the duration of coherence in a microtubule (Tarlace 2010, Tegmark 2000).

Quantum influences on consciousness are very new and still controversial. Nevertheless quantum mechanics is a valuable metaphor for brain behavior. Furthermore, thinking about quantum mechanics is fun and exercises the brain, which is a healthy activity. A particular metaphor of interest to the author is the possibility of biological qubits (Burger Aug 13, 2011, Burger 2011).

To summarize, recursive neurons may simultaneously hold true and false, such that an observation yields true (or false) with a given probability. Unlike true qubits, the underlying
information in pseudo qubits is not necessarily lost upon observation. Having said this, it should be noted that an observation is a convenient time to reset the underlying controlled multivibrators, in which case all information is lost after all. Assemblies of toggling qubits may be triggered and synchronized to accomplish powerful computations. Limitations of these pseudo qubits are: 1) teleportation is impossible, and 2) not the full \(2^n\), but rather the existence of only \(2n\) simultaneous states for \(n\) neural multivibrators. They nevertheless significantly exceed the capabilities of classical deterministic logic. It is explained below how biological qubits may orchestrate consciousness.

**What is Consciousness?**

Consciousness is not well defined (Penrose 1989). It has been defined as an ability that makes a person smarter than any machine. But this remains to be seen. At least it has a purpose: One of the purposes of consciousness is to facilitate self control.

Experiments by Libet and others demonstrate that a brain anticipates body movements well before we consciously know about it (Wegner 2002, Restak 2006). Most of us assume the other way around, that our "mind" directs our body. The author is led to conjecture that free will and ego are illusions. This deception seems evolved to drive a person to greater achievement, also a survival benefit in most cases.

The model below borrows from Dennett’s *multiple drafts* model (Dennett 1991). Here multiple evaluations of recalls are subconsciously occurring in parallel, with only a small number of evaluations ever having resulting in action or reaching a person's awareness. The author views the multiple draft model as being constrained by the laws of physics and circuit reality. The main mystery is, what is the logical architecture of these connections?

**The Memory Environment Within a Brain**

In the author's vision, consciousness is considered to be an interplay between short and long term memories. Short term memory holds only for seconds; to be anywhere near efficient it is likely distributed (Kanerva 1988, Burger 2009). This means that each sensed attribute, color and tone and so on, has its own short term memory space that never occupies the space of any other attributes. Signals that activate short term memory neurons are assumed to flow from an elaborate sensory encoding system that is not the subject of this paper. Much is being learned about sensory encoding and probable brain architecture from studies with artificial brains (Adee 2008; Haikonen 2007; de Garis 2010).

Neurons can be specialized for short term memory, for instance, when they have an internal potassium deficit, or mechanisms to inactivate their internal potassium ions (Kandel 2006). The result is, an attribute emits an extended action potential that is recognized by connecting neurons. With no attributes, there is no signal.

The activation of any neuron involves the application of excitatory neurotransmitters within close-spaced synapses, about 20 nm. The output of an activated neuron is a low energy, low
frequency burst of low voltage pulses, below a few hundred hertz, charging and discharging membrane capacitance between about -70 mV to +40 mV. Bursts from short term memory neurons persist for seconds, while ordinary logic neurons for signaling need only a few tens of milliseconds for a burst of perhaps ten pulses. These pulses radiate down axons that can be relatively long.

Once established, long term memories cannot be erased or overwritten. A plausible explanation of memory is that sets of attributes are held by small, possibly recursive neurons. To hold attributes, these neurons are marked somehow, perhaps with long term potentiation (Bliss 2004). Subsequently they will multivibrate (or generate an action potential as short term memory neurons do), if triggered, thus indicating that they hold a memorized attribute. They will not multivibrate if triggered if the attribute is not in the memory set. The result is a signal that may be read by connecting neurons. More is known today than a decade ago, but much is unknown about basic long term memory. Reasons are, small recursive neurons, like all neurons, are efficient with energy compared to solid state devices, making them difficult to observe in action, especially since they are active for only a brief time, and then only if triggered.

Brain structures can be assumed evolved to be reasonably efficient, and obviously must obey the laws of electrical circuits. This realism leads to the conclusion that long term memory neurons are organized to correspond to short term memory neurons. Layers of memory neurons that can be thought of as sparsely filled words. Each layer has a one-to-one correspondence to short term memory neurons so that reading and writing are efficient. Physically, memory cells are located randomly and duplicated extensively, so naturally given memories are impossible to localize experimentally.

Information is assumed to be memorized automatically if it passes through short term memory a sufficient number of times. Memorization and all other logical capabilities are accomplished by neural logic. Neural logic of the complete sort is known to be available; it is a natural result of synaptic excitatory and inhibitory neurotransmitters in combination with active and passive regions within neural dendrites and perhaps, also axons (Burger April 13, 2010; Mel 1994).

**Consciousness Model**

An arbitrary set of attributes in short term memory may work physically to recall images from long term memory (known in psychoanalysis as association by similarity and contiguity). In other words, a judicious recall overwrites the fading contents of short term memory. Ordinary logic constructed of neurons can explain this (Burger 2009). In this way there is an ongoing, possibly flickering picture in short term memory.

However there is more to this movie because what appears in the next frame is the subject of extensive unconscious processing. What can happen, and this probably happens more often than not, are either: 1) no recall and 2) excessive number of recalls.
Given a confused set of attributes to serve as cues, a condition of no recall is fairly common. We often experience forgetting of a certain thing but soon after, or perhaps much later it pops into one's mind. It is also noted that occasionally a hit and miss mnemonic will spur memory. Of course, sometimes there is no memory that can be recalled. A region of brain architecture is reserved to aid with recalls (cue editor in Fig. 1).

On the other hand, an under determined set of cues generally results in a plethora of recalls. This overabundance may be processed to assess the importance of each. Here it is important that processing be done in parallel to speed image movement into short term memory. If something seems critical, it is passed immediately to short term memory. From here related images including safe responses are promptly found via the cue memory. Multiple recall resolution in parallel is essential, so a region of brain architecture is reserved for this function (recall referee in Fig. 1).

Generally, a person is aware of only one thing at a time, usually something relevant and in a sense, important. Dreams and brain-storming may be like this, in which a random attribute leaks into the cue editor and causes blotchy recalls. But only the most recent, most alarming or most interesting scenarios are allowed to enter into short term memory. If they recycle there a few times, or night after night, they begin to form a long term memory.

A cue editor and a recall referee are assumed to jointly regulate consciousness as depicted in Fig. 1. These nontrivial parts will be seen to depend on biological (pseudo) qubits.

Cue Editor -- Cue editing is necessary when memory searching involves conflicting attributes (or when there are no matches in long term associative subconscious memory). Figure 2 shows a plan for a cue editor, minus the circuit details. The dots represent pseudo qubits. Each has the ability to be zero, one, or some probabilistic combination of both zero and one. Initially they are all cleared to zero. Classically the process of clearing is logically irreversible because information is lost, and normally a small amount of energy is dissipated somewhere. Biologically, however, it is not clear how much energy is lost (beyond what is normally dissipated by an action potential). Ideally clearing is slow enough so that borrowed energy is returned to the appropriate ions where it came from.

Any qubit is capable of being set (toggled to one) if a logical one is applied from above. After a successful search these circuits are cleared to zero by a signal applied on the right, so it is ready for another set of cues.
Fig 1 Underpinnings of Consciousness
Fig 2 Architecture of a Cue Editor

Going back to the beginning, signals from short term memory are initially latched in neural qubit register R1. At first, each entry is 100% true or 100% false. Simple neural logic subsequently enables an associative (parallel) search of long term memory.

If it should happen that there is no response from subconscious memory, then simple logic permits the ineffective attributes to transfer to R2 and clears R1 in preparation for the next set of attributes.

Later, when the brain is not very active, it may happen that R1 is empty for a brief moment. Simple neural logic applies the contents of R2 to perform another memory search. However, this time each of the true qubits is given a given small probability of being zero. It is as though some of the original attributes are randomly selected and removed. Recalls using the revised attributes are more likely. Eventually, perhaps after several trials, there will be recalls, at which time R2 is cleared in preparation for updated cues.
In the event that ineffective cues appear in both R1 and R2, simple logic moves everything down to R2 and R3 and clears R1 for the next set of cues. Then as time permits, R2 and R3 are adjusted probabilistically in an attempt to obtain a recall. There is always an available row since the evolved number of rows is matched to the rate at which they are needed.

There is a memory search signal that serves to initiate a reading of a register in the cue editor. Search signals are assumed to occur under certain conditions proposed as follows: 1) Body senses have placed new information into short term memory; 2) A new recall from long term memory has arrived into short term memory; 3) The contents of short term memory have faded to, say, below 20% of their previous number of attributes. A cue editor that works as above is consistent with much of our subjective experience with forgetting and remembering.

Recall Referee -- Quite often, it seems, the cues are underdetermined, in which case many possible images will come forth in rapid succession as permitted by long term memory. They do go into respective registers of biological (pseudo) qubits as depicted in Figure 3. Simple neural logic assures that each image is individually multiplexed into cleared registers. Here an indices of importance or priority are computed.

In a given row, qubits are assumed to be in communication via a simple axonal bus, so that signals from given source qubits can instigate controlled toggling in given target qubits, ideally disjoint from the source qubits. A system like this is capable of complex computations (Burger 2009). The system is logically reversible and so is potentially efficient with energy. Consequently many recalls may be indexed for importance in parallel without significantly taxing the brain.

This paper does not specify exactly how priorities are computed, but surely the computation will contain emotional factors, and survival factors, assumed to be integrated into each word of long term memory. Other factors relating to conflict resolution have been proposed in connection with artificial intelligence (Franklin 1995; Anderson 1983) and these have been well discussed (Dennett 1991).

When short term memory is ready for a new image (essentially a ready signal goes true) then completed priorities are compared. The highest is selected by a priority selector. Again, this would use reversible qubit toggling to determine the highest priority. The image with the highest priority is subsequently gated into short term memory. Soon after, the Processor from which this image came is cleared in readiness for another image. There is always an available row since the evolved number of rows is matched to the rate at which they are needed.
Sleep -- Under the above architecture, sleep can be considered to be a result of signals that the body is physically tired. A recall selector can sense this so that the priority for sleep increases substantially while the priority for all else decreases considerably. Natural sleep permits dreams and some low level of consciousness (in the sense that one can be awakened). In contrast, unconsciousness is the result of disabling neurons by biasing them with potentials or with chemicals, or otherwise damaging them.

Learning -- Indirectly, learning pertains to a certain aspect of the above priority computer and so is mentioned briefly. Learning is not the same as memorization, which modifies the internal contents of words of long term memory. In contrast, learning is taken here to mean the creation of hidden state machines that step between previously established words in long term memory (Burger July 5, 2010). State machines permit complex and subtle action-filled procedures without a requirement for conscious thinking. Once addressed they enable
such everyday activities as walking, talking and much more. Learning like this avoids the relatively inefficient process of passing information through the apparatus of consciousness.

Learned mathematical procedures can in principle employ the very same qubits that are used for the recall referee. Nearly everyone at one time or another has witnessed the amazing mental results produced by gifted savants. It is thought that subconsciously they may be running qubit registers in parallel (Burger 2011). For instance, partial products can readily be performed in parallel and then accumulated using circuits vaguely akin to those in a priority encoder. Similarly, parallelism could explain such feats as the mental identification of prime numbers and calculation of pi to many places. A diagram is envisioned as in Figure 4.

![Diagram](ParallelMentalProcessing.png)

**Fig 4 Parallel Mental Processing**

As an example of mathematical procedure follows: Consider a previously learned method identified as method $\alpha$ to be applied to $2x + 5 = 11$ to solve for $x$. This particular task requires only one register of toggling qubits. Mathematical attributes are held in associative memory as readily as the hallmarks of any other landscape. Candidates for attributes are specific locations in memory for $2, x, +, 5, =,$ and $11$ and the form $Ax + B = Y$ using method $\alpha$.

Figure 5 depicts how the sight of an equation activates a certain location in associative memory. This location is step 1 in a state machine. A state machine, if uninterrupted, will
step through its states without having to be directed by cues from short term memory. In this sense it is efficient because each step does not have to be pondered consciously.

For the equation and method given, a state machine must accomplish the instructions listed below:

Table 1 Determining that $2x = 6$

1. Move 11 to arithmetic area (leaving 0)
2. Move 5 to arithmetic area (leaving 0)
3. Compute or look up associatively $11 - 5 = 6$
4. Return result (6) to arithmetic area
5. Move 6 to the position of 11 in problem area
   $2x = 6$ appears in problem area

Detailed instructions are stored in long term memory are recalled to act upon the toggling qubits. A local axonal bus facilitates moving mathematical attributes (bit) from one place to another.

Once $2x = 6$ is permitted into short term memory, the first state machine ends. An associative search now locates $2x = 6$ using method $\alpha$. A second state machine may accomplish the instructions listed below to arrive at $x = 3$, at which point the second state machine rests. Detailed qubit toggling instructions are available elsewhere (Burger Oct 4, 2010).

Table 2 Determining that $x = 3$

1. Move 6 to arithmetic area
2. Copy 2 to arithmetic area
3. Replace 2 with 1 in problem area
4. Compute or look up $6/2 = 3$
5. Move 3 to where 6 was in problem input area
   $x = 3$ appears in problem input area

Summary and Conclusions
To summarize, a hypothesis has been presented that consciousness is a natural result of neurons that become connected recursively, and work synchronously between short and long term memories. This hypothesis is more sophisticated than previous connectionist schemes in that it depends on biological (or pseudo) qubits.

This work begins with distributed short term memory in which the various attributes of a mental impression each have their own fixed locations. Each attribute is assumed to be in more than one location, since we know that memories cannot be physically localized. Short term memory is directly activated by signals from the five senses and also by successful
recalls from subconscious long term memory. Radiating from short term memory is a bus of axons that move more or less intact through a cue editor and down into long term associative memory.

![Diagram of rows of qubits running in parallel](image)

**Fig. 7** Seeing an equation evokes a state machine to solve it

The cue editor serves mainly to resolve conflicting (over determined) cues, and cues for which there are no memory matches. Ineffective cues are not discarded but are stored in a row of biological qubits. Before searching again, each ineffective attribute is enabled to be read with a small probability that stored true signals will be observed to be false. The process of randomizing is repeated until finally, recalls are obtained, after which the subject row is cleared. This system accounts for the common observation that forgotten information often pops into one's head later, at an unexpected moment.

An ancillary benefit of this system is that the attributes of a mnemonic are also adjusted subliminally to aid memory. As conflicting or ineffective cues arrive, they push older conflicting cues down into another row of qubits. There is nearly always an available row since the number of evolved rows is matched to the rate at which they are needed.

Associative memory is such that it responds to any arbitrary combination of applied attributes. Parallel to each axonal network going down into long term memory is an axonal
network that carries signals up from long term memory for subliminal processing. These signals move more or less intact through a recall referee where they are analyzed for importance. A recall referee is needed to deal with the common situation of multiple recalls. Most recalls are useless, but important information is gated directly into consciousness in the form of actions and impressions in short term memory.

The process of sorting multiple recalls according to importance is accomplished by logical rows of toggling qubits operating in parallel, one row for each recall. Toggling qubits within a given register may be made to communicate with each other via a simple row bus, and may serve to accomplish calculations as required to determine an index of importance, that is, priority.

The necessary sequences of instructions are assumed to attached and stationary to each row of qubits, permitting them to calculate independently without synchronization, and in parallel, without recourse to additional recalls. Regularly a priority selector reads the completed priorities and enables the most important recall to produce actions, and images in short term memory. Subsequently that row is cleared to make room for new candidate recalls. The rate of recalls is assumed to be matched to the parallel capabilities of the qubits so that new recalls always have an empty row.

At the end of the day the body may cause adjustments to the computations of priorities so that natural sleep is facilitated.

With modification, mathematical operations may be accomplished in a row normally used for calculating priority. A natural extension of this idea is that parallel rows of toggling qubits may serve to increase human abilities via parallel processing, as a possible explanation for gifted savants. In this application, depending on what a savant has learned to do, it is speculated that instructions are brought up from long term memory to direct the rows of qubits to a specialized result. With adjustment, the priority selector may double as an accumulator to facilitate mental calculations.

In conclusion, a system of consciousness has been synthesized that is underwritten by physical circuits. Under this system, consciousness is generated by biological qubits that develop from ordinary neurons. A person is unaware of this underlying capability. Part and parcel of this system are that actions depend chiefly on evolution and learning, and not so much on timely personal choices.

Neurons in the form of pseudo qubits are passive until needed and then synchronized to work in parallel. Such qubits are organized into rows to match the logical structure of distributed short and long term memories. Qubits in a cue editor serve to ensure that many recalls are obtained from long term memory. Subsequently qubits in a recall referee manipulate recalls in parallel to determine highest priority for overwriting the contents of short term memory. This creates what is termed consciousness. The system described
above, although at the level of a hypothesis, is physically plausible and does not violate natural laws.

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