

A Toy Model for Memory: Memory Can Be Represented by a Quantum Mechanical Wave-Function

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Abstract: The meaning of memory, quantum mechanical wave-function and their relationship are investigated. The memory of a neural system is discussed in quantum mechanical sense. The way a memory is created, and remembering process is given.

Key words: Memory, brain, quantum theory

Hafıza İçin Ham Bir Model: Hafıza, Bir Kuantum Mekaniksel Dalga Fonksiyonu İle Temsil Edilebilir

Özet: Hafızanın anlamı, kuantum mekaniksel dalga fonksiyonu ve bunların birbirleriyle olan ilişkileri incelendi. Bir sinir sisteminin hafızası kuantum mekanik bağlamında tartışıldı. Bir hafızanın oluşması ve hatırlama süreci verildi.

Anahtar kelimeler: Hafıza, beyin, Kuantum kuramı

1. Introduction

How do we remember, what makes us remember, why do we remember? Possible answers to these questions can be given by guidance of Copenhagen interpretation of quantum theory [1-3]

In [4] it is quoted that

The core message of quantum theory appears to be that the basic realities are 'knowables', not 'be-ables': they are things that can be known, not realities that exist yet cannot be known.

In this sense, since it is more epistemological than it is ontological, engagement of quantum mechanics with memory rather than brain itself seems more peaceful unlike other approaches [5,6].

2. Quantum Mechanical Memory

In quantum mechanics a physical reality is represented by a wave function which, in principle, includes all information about the reality it represents. The two parts – memory and its present environment– evolves as a single combined system. But here, the present environment has another duty; in addition to being a part of the combined system, it simultaneously plays the measuring apparatus role on the memory. In this

manner, we can represent our memory and its present environment with a wave function.

Wave function in memory (or memory which totally is a wave function in quantum mechanics manner) is constantly collapsing onto registers (component wave function of the whole wave function). Collapse occurs simultaneously on more than one register. Every collapse onto a past register is also a register. This collapse occurs in such a way that one may get a perfect result according to the environment. Namely, the result is much more suitable than any other collapse possibility. When we think of what we remembered we realize that the result could also be something else which is less suitable than what we remembered. This recall may sometimes move away from perfectness. If so, the “scanner” (here it is the *context*) did not scanned every part in the memory; or may be it scanned one of the sub-spaces of the memory, or there are places that the scanner could not scan (for some reason) at that moment.

Our brains (neural networks of the living organisms, in general) continuously perceives (with sense organs and/or by thinking). The perceived facts, each and every one of them, leave a sign in the brain, no matter we are aware of this perception or not. These signs are recorded in the related regions (to be recalled later). The signs are not recorded as individuals, instead they are recorded with the environment they are in, as a set. The elements of these sets are interconnected. Any element of this set can be recorded as an element of another set having connections with some other set elements. This makes the memory to recall things with some inputs that seem not related. Such inputs stimulates the recorded sets in nervous system; that or another element in the set, which has connections with elements of some other set, is stimulated. This goes on until the nervous system become aware of the connections, that is it remembers. From that time on it can trace back to become aware of the relations between elements of different sets.

The record region need not be (mostly, is not) a physical region. These regions are subspaces of the whole space of the memory. Namely, the Hilbert space in which the memory wave-function is represented.

The recording procedure may enlarge the Hilbert space or makes the records new wave-functions in the existing space.

Now, we can give a definition for recall: As a wave function, memory is a weighted combination of wave functions of the facts it includes. At an “instant”, memory collapses onto one (or more) of these facts;

$$|memory\rangle = \sum_{\pi} c_{\pi} |previousfacts\rangle_{\pi}, \quad (\text{a wave function}).$$

The definition of a measurement operator on this system (neural system) can be given by quantum mechanics as

$$projective\ measurement = |percieved\ facts\ at\ the\ instant\rangle\langle percieved\ facts\ at\ the\ instant|$$

What makes a system a neural system is the permanence of such measurements, because by this way the system can create a memory and uses it.

3. Remembering, and Creating New Entities to Remember

Now we can discuss what happens when the brain remembers. Memory collapses to an eigenfunction of the perceived facts at the instant of perception. The result of this collapse, $\{previous\ facts\}$, is one of the records in memory or a brand new record. Such a new record means a new fact with new connections, or an existing entity with new connections. The depth of the track that record leave behind (the last time it was recalled) determines the probability of that record to be remembered in the future. Whatever this probability is, a recalled fact leaves a deeper track in memory -in comparison with the previous one and transfers to an upper-space (Hilbert space) (By transfer to an upper-space its meant that new connections between the remembered and other entities created, or an existing connection is strengthened.) This makes an entity to be in sight more than it was. This makes memory to have a larger (including the previous one) Hilbert space for the same fact, in other words it gets a wider perspective. Every “wider perspective” makes the facts to be perceived from a wider perspective. In this way, a subject can be learned deeper if the time taken to learn it is shorter.

When the author was a child, in order to learn better and not to forget later, he had tried to forget a fact immediately he learned it. Today he realizes that this action is the effort of recording a new fact in the memory, remembering it later, and by this way making it more permanent wave function having a greater weight.

Among the records in memory the most appropriate one(s) are “chosen” by the environment (context), like the wave function collapse procedure. The environment, which is present at the time of record, determines the weight of the record as a wave function: A sound of a word, which has more than one senses, evokes one of them depending on the context (environment). The sound of the word calls its meaning together with the other facts that it was recorded together. This is true not only for our senses of sounds. It is valid for our all senses, in general, for our whole neural system. For instance, the facts that a kind of fabric makes one remember are different when someone else touches a cloth and understands, or not, the type of the material. And same type of material recalls different records in different environment (contexts) to one person. Such a *record all* process explains treating information in context [7].

The records are not recorded as individual components. Instead, more than one parameter -in general- of the context (environment) is recorded. When the wave function corresponding to a parameter collapses, the defined procedure makes the others, recorded with that one, to be recalled (the wave functions of them to collapse) too. For example, the scent the author smells when he walks on a street of his childhood took him to those days. His existence in that street prepare his memory to remember the related records. If he smells the same scent in a different environment (in a different context) then the probability that he remembers another record -recorded together with some components of this different environment- would be greater. If there isn't any such record, then the probability of recalling the records of childhood street would be less than the previous one. Another example; in an examination the author as the

lecturer was sitting on the desk and shaking his feet. He instantly remembered a friend's face: His high school maths teacher in an exam was sitting and shaking his feet like the author did; he was playing with a chain in his hand. After the exam hour one of my high-school friends whose exam was not so good was crying, and cursing at him. The author recalled her face; a crying, smiling and cursing face. Though these seem to occur serial in the neural system, such a recalling process is like looking inside a bundle, it occurs instantly. Like perceiving the stuff in the field of vision when one looks inside a bundle, one recalls the entities, those recorded together, in *the field of recall* (like field of vision) when one remembers a record (collapse of wave function onto a component wave function that includes more than one records). Remaining stuff can be recalled as one thinks on the previously recalled facts. This is scanning the Hilbert space with the measurement apparatus. It is like shedding light on this space. We are familiar with such a parallelism in quantum mechanics: At one time more than one measurements can be done on one physical reality. By this way our brain, like a quantum computer, is able to perform two or more computations simultaneously [8].

4. Conclusion

Instead of brain, memory's quantum mechanical description seems more peaceful. In this study, how a memory is created, and how remembering occurs is discussed. Memory -a wave function of a total sum of wave functions- remembers in cases there are recallers of its component wave functions. Like, a wave function collapses onto an eigenfunction of a physical observable when a measurement apparatus measures that physical quantity and gives an eigenvalue corresponding to the eigenfunction; a memory collapses onto a register when context includes a recaller of the register. Each and every component and parameter of the context (environment) may be a recaller. As it takes on such a task, itself (a parameter of that context) also becomes a component of the memory-wave-function from that instant on. The recaller and the entity that it recalled leaves a deeper sign, so that it becomes a more favorable wave function (that is, it will have a greater weight) since it is recalled. This will make it to be remembered more easily than before.

Among others there are two questions (seems important to me) needs explanations with the perspective described above;

Question 1: What determines the importance of the registers (It is meant the easiness to be recalled)? For some, people's faces are more important, someone remembers the roads, someone remembers the scents more easily than the others. Some does not forget a formula (s)he saw, some needs to lots of things to be registered simultaneously with a formula to remember it.

Question 2: What does a person remember at the time of death? How does (s)he express it? With what word order?

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