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The cause of Alzheimer's Disease & Relative Dementias is Brain Information Processing Impairments

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Abstract

In the last decade, neurodegenerative diseases (such as Alzheimer's disease, Parkinson's disease, and various forms of Dementia) have become a challenging problem facing contemporary society, placing on it a strong economic, social, and healthcare burden. Despite huge and long-lasting efforts, the progress in solving these problems remains unsatisfactory. The reason for that – the causes of the diseases' origination and progression remain unclear and unexplainable. In a problem--solving attempt, a network of research institutions has been established and launched. Their main efforts are aimed at studying the mechanisms that are responsible for the diseases' onset and development. Mainly, the mechanisms of genetic, epigenetic, molecular, and environmental factors are being investigated. For unexplainable reasons, information processing mechanisms are not even mentioned in this list. Why? The balk of the brain's activity is information processing – this is a generally agreed and accepted dictum. The only possible explanation for such a lapse can be: the contemporary neuroscience (neurobiology) knows nothing about what information is and what information processing stands for! The purpose of this paper is to somehow repair and possibly reshape this unbelievable situation.

Keywords: Alzheimer's disease

Introduction

As heralded by the World Health Organization, Alzheimer's disease (AD) and related dementia (ADRD) are the principal causes of disability, debility, cognitive impairments, and finally death among the elderly part of the contemporary human population [1].

It is generally agreed and accepted that Dementia is a broad term used to refer to a wide range of brain diseases. AD is one of the forms of dementia, the most common form - Alzheimer's disease accounts for 60-70% of the cases of dementia [1].

It is also agreed and accepted that ADRD poses a strong economic, social, and healthcare burden on the society. The lack of knowledge about the circumstances of ADRD commencement and progression exaggerates the problem.

To meet this challenge, a wide network of research institutions and scientific foundations has been established, dedicated to studies of ADRD etiology, the routes of ADRD beginning, and progression.

Their research efforts are directed at investigating various mechanisms that support and drive ADRD etiology. Among them, the mechanisms of genetic, epigenetic, molecular, and environmental traces are prevailing.

I am not a doctor, not a microbiologist, not a neuroscientist, not an ADRD researcher. I am an engineer who once was engaged in problems of Computer Vision, Robotics, and Artificial Intelligence. In this way, I was once engaged with problems of human brain functioning. The main lesson that I retained from these my engineering practices was that the brain at work is busy with information processing.

It was a great surprise to me that the study about mechanisms and causes of brain disorders and diseases does not pay any attention to brain information processing mechanisms!!! Why? How such an important feature of brain activity can be overlooked and disregarded in ADRD investigations?!

My answer to this question is only one – the ADRD research community does not have the slightest notion about what information is and what information processing stands for.

In this regard, I will try to close the gap (in the ADRD research activities) and explain to the ADRD research community what they have to know about these just-mentioned topics. I hope, that this new knowledge will critically advance and accelerate the ADRD Research investigations.

And So – What is Information?

We live in the Information Age, and today the most commonly used word is “information”. However, despite its widespread use and usage, a consensus definition of Information does not exist.

The concept (of “information”) was first introduced by Shannon in his seminal 1948 paper “A Mathematical Theory of Communication”. Then other scientists joined the venture – Kolmogorov, Fisher, Chaitin, and others (see [2, 3, 4] and references therein). However, none of them did not try to define what is “information”. They were busy with the “measure of information”. That was enough to improve the performance and reliability of technical communication systems.

In the year 1949, Shannon wrote: “These semantic aspects of communication are irrelevant to the engineering problem... It is important to emphasize, at the start, that we are not concerned with the meaning or the truth of messages; semantics lies outside the scope of mathematical information theory” [2].

In modern sciences, and especially in biology, the needs of communication cannot be reduced only to the optimization of the tech-

nical parameters of the communication system. The semantic aspects of the message are of a paramount importance, and thus must be met.

Following the soul and spirit of this requirement, I have developed my own definition of information. (Interested readers can look into the references [2, 3, 4]).

My definition of information sounds today like this:

"Information is A Linguistic Description of Structures Observable in A Given Data Set."

In a data set, the data elements are not distributed randomly, but due to the similarity of their physical parameters, are naturally grouped into some kind of clusters or cliques. I propose to call these clusters primary or physical data structures.

In the eyes of an external observer, these primary data structures are arranged into larger and more complex agglomerations, which I propose to call secondary data structures.

These secondary structures reflect the observer's view of the grouping of primary data structures, and therefore they could be called meaningful or semantic data structures.

While the formation of primary (physical) data structures is determined by the objective (natural, physical) properties of the data, the subsequent formation of secondary (semantic) data structures is a subjective process governed by the conventions and habits of the observer (or a mutual agreement of an observers' group).

As said, the description of structures observed in the data set should be called "Information". In this regard, it is necessary to distinguish between two types of information – physical information and semantic information.

Both are language descriptions; however, physical information can be described using a variety of languages (recall that mathematics is also a language), and semantic information can be described only using the observer's natural language. (See [3] for more details).

An important consequence of the above definition of information is the understanding that information descriptions always materialize as a set of words, a fragment of text, a narrative. In this regard, an important note should be made – in biological systems, these text sequences are written with nucleotide letters and amino acid signs, (indirect evidence of this in [5]).

This turns the information into a physical entity, into a "thing" [6]. With its weight, length, and other physical properties. For the purposes of our discussion, this is an extremely important remark.

Information Flow and Brain Information Processing

It is generally agreed and accepted that the human brain is an exceptionally powerful information

processing device. In one of my early publications, I devoted a special chapter to this issue [3]. Therefore, to save time and space, it seems reasonable to me to repeat here only some selected fragments of this article.

So, let's repeat. The brain is processing information. Neurons are the functional units that do this work. Despite their discrete structure, neurons are not separate functional units – successful information processing requires close cooperation between coworking units. For this reason, neurons are connected in a network in which they communicate with each other: transmit, exchange, replace, expand, and enhance – in a word, jointly process information. This transition of information between interconnected (at dif-

ferent levels of the organization) neurons even received a special brand name “Neural Information Flow” and became the subject of close research and investigation.

From the point of view of interneuronal communication, neurons can be considered as a chain in which two consecutive units are connected through synaptic contact. Each single neuron consists of three connected parts: dendrites (the input part), cell body or soma (the main part), and axon (the output part). Understanding the functional role of these neural parts and how information flows through them has been a major goal of neuroscience for much of the past century. However, for some reason, among the three parts facilitating the flow of information through the neuron chain, the axon part has been the most explored and studied [7].

The concept of neural information flow, which is generally accepted today, assumes different forms of information presentation in different parts of the information flow chain. The input part (dendrites) is dominated by chemical neurotransmitters and flows of electric charges (ions).

The accumulation of input electrical potentials and the emission of a resulting action potential are characteristic of the somatic part. Propagation of an action potential in the axon and then again conversion of it into chemical vesicles (at the terminal end of the axon) – all these forms are multiple expressions representing information in a single neuron path of information processing.

This does not seem to me plausible. Nature is conservative, it is hard to believe that at different stages of one unit of information processing (dendritic input - soma - axon - axon terminal - synaptic cleft) one part of the path is realized as a molecular cargo package, and the other parts represent information in a completely different form. For example, the package of axon spikes represents the transfer of information in the axon. That seems to me absolutely incredible.

The idea proposed in this article that information always (at all stages of the information flow) appears as a materialized text string (written in letters of nucleotides and amino acids), and as such is being altered (processed) at all stages of information processing hierarchy, such an idea seems to me a much more reasonable and plausible. Explanation of what happens to information at each stage of the information flow path is one of the goals of this paper.

And an additional remark – As it follows from the previous paragraphs (about information definition) Information processing is busy mainly with semantic information processing. This is carried out in a hierarchical fashion, where the semantic information of a lower level is transferred to the next higher level, where it becomes incorporated into a structure of a higher complexity composed at this higher level. This aggregation is carried out according to subjective (system’s, observer’s) rules kept in a prototypical (referential) structure called the system’s (observer's) memory. Such memory is stored in different parts of the neuron’s body, where different stages of neuronal semantic information processing are being accomplished.

New Insight into Information Flow and Information Processing

The notion of information as a material (physical) entity drastically reshapes the existing landscape of information flow and information processing.

For example, the concept of axon transport of action potential spikes and spike packages (as information carriers) become not valid anymore and must be promptly rejected or modified.

The blurred concept of reference memory present at every stage of semantic information processing must also be promptly untangled – the reference memory (as all other memory arrangements) must be provided with a physical space for its accommodation. This requirement must be and is fulfilled at each stage of information processing – at the dendrite stage this is the dendrite spines, at the soma stage this is the organelles, at the axon stage this is the oligodendrocytes and Swann cells wrapped around the axon body.

These memory (information) storage containers must have the ability to change and modify their stuff, (when the system is in a learning stage, or the memory is changing its form from a short-time memory to a long-time memory). That places a requirement for memory's physical accessibility, in other words, necessitates new rules of information processing and new routes of information flow.

With all of this in mind, we can now move to a discussion about the main purpose of this article – what all this means for a better understanding of the onset and development of Alzheimer's disease and Relative dementias (ADRD).

ADRD and the Information Materiality

Now, as the basic concepts of information and its processing are clear and obvious (to us), we can begin to discuss how all this affects our understanding of Alzheimer's disease and other dementias.

It seems to me quite natural to assume that the cause of all disturbances and disorders in the brain's functioning is the disturbance and disorder of the process of information processing (in the brain). It seems quite natural that there can be a variety of such disorders (some more serious, some less serious). But it seems reasonable (to me) to focus on just one of such disorder, the one that seems to be the most serious and important, because it is common to all stages of information processing, and in such a way to all types of brain disorders and brain diseases (dementias).

I will have to start talking about this disorder somehow from afar. It is well known that any processing activity is always escorted by an accompanying process of waste production, a tightly connected process of waste creation.

This is a general natural law, and therefore it will be natural to extend it to the processes of information processing in the brain, the processing of semantic information, which is the main information that the brain is processing. As it was already mentioned, semantic information always looks like texts (materialized texts written in nucleotides and amino acid signs). These texts are being processed. It is in the course of processing these texts the waste evolves. The waste is composed of pieces of text, residual fragments of the processed information, or full-text structures that were not been processed because they do not meet the prototype text examples that are handled at this processing level. (If you remember, this is how semantic information is being processed: according to prototype patterns of information, which are stored in the memory of this processing stage).

To maintain the functionality of the system, produced waste must be removed from the place where the processing is fulfilled, and, consequently, it has to be subjected to further processing (dispersing and breaking) and prepared for further disposal or removal from the processing place.

Neuroscientists know nothing about information, about information processing, about the information garbage that appears during the processing of information, and about the difficulties of the consequent trash processing, recycling, or removal, However, they are well acquainted with TAU proteins [11], which appear from nowhere in the neuron cell and in its immediate surroundings. They are familiar with lysosomes, autophagy, and immune cells – all these are the mechanisms that are busy with the tau invaders processing and removing from the neuron cell, [8, 9, 10].

The connection between cellular debris and ADRD is well-known and established (recall the definition of taupedia and its treatment, [11-14]. Attempts to eliminate cellular debris have been ongoing for a long time and are successful. But this is a misunderstanding. Cellular debris is a natural accompaniment of information processing. And therefore, their presence is mandatory. Proper handling of this waste is the cherished goal and the responsibility of ADRD researchers.

I invite my fellow neuroscientists to urgently familiarize themselves with and to master a new understanding of the phenomena (or concepts) of the brain work, which are still unfamiliar to them.

I suggest that they urgently switch (in their work) to the information principles of brain functioning.

Brain Diseases in the Light of Information Processing

As mentioned above, the processing of semantic information in different parts of the neuron and throughout the entire information flow is accompanied by the appearance (emergence) of information garbage. This is a natural process that makes no sense to fight. Nature has created special mechanisms for the removal and further processing of this waste. Disturbances and malfunctions of these mechanisms are the cause of neurodegenerative disorders and neuro diseases.

Since the control of these mechanisms (of debris clearance) is carried out at the genetic level, the correction and repair of these mechanisms must be done also at the genetic level.

Today this is a completely resolvable problem, feasible with the help of genetic engineering and CRISPR technology, [15].

Some Concluding Remarks

The main purpose of this article was to introduce ADRD researchers to the concepts of “Information”, “Information Processing”, “Information Garbage”, and other knowledge arising from these concepts, which (possibly) will effectively accelerate and enrich ADRD research and subsequent ADRD understanding, diagnosis and therapy.

I think I have successfully coped with this task. I hope that all this will be interesting and useful for ADRD researchers and developers of ADRD therapy.

However, I would like to mention here some more details related to the processing of garbage in the neural system of the brain. As follows from the above texts, the processing of information garbage in neuron cells is not a specific feature of the cell type. No, this happens in any (in all) brain cells. Therefore, we can say that ADRD can occur in any brain cell. Today's differences in disease symptoms are determined not by different forms of the disease, but by the differences in neurons’ functional activity. However, the appearance of information garbage is directly linked with the neurons’ functional activity

In this regard, I would like to mention some more details related to the processing of garbage in the brain's neural system. As follows from the above texts, the processing of information garbage in neuron cells is not a specific feature of the cell type. Thus, the uniformity of information garbage processing can be used for early diagnosis of ADRD.

As it is known, the processing of information garbage takes place in several stages - the garbage is removed from the neuron cell (from its different parts where information processing does occur) into the near-neural space (usually called glia), where the garbage is further processed and then released into the blood. With the blood, information garbage reaches the liver. From the liver – into the urine (and possibly into feces), with which it is finally removed from the body.

We are interested in these details of the evacuation (from the body) of information garbage only because at the stage of transportation of this garbage by blood, the amount of information garbage in the blood can serve as an indicator of the disease presence and its stage. This is already used today as a way to detect and assess the state of the ADRD based on the presence of specific biomarkers of various diseases in the blood (i.e., hunting for specific, specific pieces of information garbage), [16, 17, 18].

But in our case, the way of using biomarkers is fundamentally different from those accepted and existing today. First of all, the presence of a certain number of biomarkers in itself does not say anything - information garbage is always present in the blood of the subject, because information garbage is a natural byproduct of information processing, and as such, it is always present in the blood. An indicator of illness is the change (an increase or a decrease) in the level of information debris in the blood.

A decrease in the level of information garbage indicates that the mechanism for removing garbage from the cell is damaged, that is, the garbage is not removed and remains in the system, clogging it and stopping the needed information movement within the system, stopping the flow of information in the system.

An increased level of informational garbage in the blood indicates a possible dysfunction of the cleaning mechanism. That is, it does not distinguish between garbage and useful (epigenetic) information. And destroys the epigenetic memory (which is the information prototype, conserved in the system for semantic information processing). Loss or partial impairment of this memory leads to degeneration of the system. (For example, various forms of sclerosis). An increased level of information garbage in the blood thus indicates precisely this information processing dysfunction - the destruction of epigenetic memory.

I hope that these clarifications and comments of mine will be well accepted by the ADRD research community. Even though all my statements are hypothetical. As stated above, I am an engineer, not a neuroscientist, not a doctor, not an ADRD researcher. I do not have a laboratory and the staff that would verify the accuracy of my hypothetical conclusions.

I sincerely hope that the ADRD research community will favorably assess these notes of mine and that some atmosphere of mutual understanding and fruitful cooperation will arise between us.

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