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EDITORIAL

A New World of Learning

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ABSTRACT

Exponential development of information and communication technologies is changing the world of learning. As a consequence of exponential exposure to media and information flows, our brains are adapting and new skills are arising. This especially occurs with the new generation of people who encounter media and information tools at the earliest stages of life. Although many of us are aware of such changes, there is very little research-based information to explain them. In recent years, evidence was presented demonstrating neuroplastic basis of human brain adaptation, although neuroplastic mechanisms are still poorly understood. Today's schools and universities are still analogue, whereas the students can be said to be digital. The educational system does not properly recognize the skills of the new generations and does not respond to their needs. New aspects of social evolution suggest that we should also think not only of adapting our learning skills, but also our social skills. These skills should be integrated into all learning processes, from preschool education to lifelong learning. The aim of this editorial is to facilitate discussion within the medical profession about the arising new world of learning.

Keywords: Learning, Generation Y, Information and communication technology, Neuroplasticity.

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INTRODUCTION

Readers of this journal, largely physicians and medical professionals, are traditional learners who very often need to organize the learning process for new generations of nontraditional learners, in many cases 18-year-old students. Of course, they try to provide the best possible teaching and to create an impact on their students in a way similar to that they experienced during their education. Needless to say, they also try to obtain the best possible results.

As medicine develops with the development of technology, learning process needs to be developed as well. This is true not only for those specialists who focus on the learning process, educators and psychologists, but also for each individual in the rapidly developing society. Therefore, for every specialist who is supposed to work with people, especially physician, it is essential to understand the learning process itself.

When we plan the learning process or any type of training for our students we should ask ourselves what their world would look like upon the completion of their training. If we are dealing with freshmen and providing medical training, we might ask ourselves what the year 2020 might turn out to be like for them. At that point in time the present-day freshmen will most likely be searching for jobs, planning their careers and families. We should also ask ourselves what the society can be expected to evolve into at that time. The questions which we need to ask ourselves are even more demanding for primary and secondary school teachers who are currently preparing their pupils for life in 2030 or in 2022, respectively. Of course, these questions are enormously important for all those who plan the learning process, develop curricula, train future trainers or make decisions regarding education.

When we ask ourselves these questions, we should take into consideration the extent in which the world has changed in course of the past 10 years and try to evaluate the extent in which the world is likely to change 10 years from now. We should make ourselves aware of the important things that have changed during our own lifetime, such as telephone and computer technology, music media, the uses of internet, connection speeds, etc. especially of the ways in which all these changes would have affected the process of learning. We should then apply such insights to evaluate the extent of change our students are likely to undergo. By 2020, a present-day first class pupil will be 16 years old, a secondary school graduate will be reaching the age of 27 and a 2nd cycle TE graduate will have reached 33 of age. We should keep in mind that we are living in exponential times, that the learning process is changing under the influence of technology, and that the human brain adapts to all this due to the normal survival-driven process of biological and social evolution.

We should also keep in mind that the industrial civilization is, at the same time, vanishing and being replaced by the new, emergent, knowledge-based civilization. However, the educational system that we still have has been conceived for the needs of the industrial civilization and we (the teachers) were once educated to become part of the industrial society. In addition, new and worrying trends will affect life in the 2020s: unsustainability of the global financial system, global warming, global competition and redistribution of economic power, lack of fossil fuels, lack of food and water, emergence of the surveillance society, etc. Also, many optimistic trends will emerge with the advancement of nanotechnology, biotechnology or astrophysics. All this will affect life in 2020s and should be taken into account when we plan the learning process.

In this communication we will briefly analyze how the rapid information and communication development affects the process of learning and how new generations of people, our current pupils and students, respond to these changes. We have no intention to make an indepth analysis of all relevant sources, the aim of this article being primarily to stimulate discussion the result of which should be integrated into the process of curriculum development and into the planning of learning exercises. First, we will try to attract attention to the fact that the world is rapidly changing, than we will analyze how new generations are adapting to the new world and, finally, we shall discuss the ways in which the educational system along with the educators should respond to these changes.

The World is Rapidly Changing

Most of the readers of this article are aware that the world is changing: however, this awareness is often not clearly articulated in the ways in which we actually analyze the societal change. The change is rapid, exponential, and thereby evades the usual methodology, assessment instruments and communication platforms used by contemporary science. Thus, it is essential to understand all these changes, the responsibility of research in social sciences being enormous when it comes to adequately addressing issues and creating appropriate response platforms, especially for decision makers in the political process, at least in Western democracies. The aim of this brief analysis is therefore to shed some lights onto the processes that occur in the area of learning for the new generation of learners who are breaking into the new learning landscape. Let us therefore present a brief timeline of changes which took place in the world of information management, which in itself is a major driving force that causes major alterations in the learning process (Fig. 1).

The first analytical engine, the first effort to automatize data processing, was constructed by Charles Babbage, 179 years ago (Fig. 1), and the first transistor, the analytical unit which revolutionized information processing was invented 88 years ago.[1] Even 29 years later, it was not seen as a device with potential use.[2] In the meantime, in 1946 the ENIAC was produced (Fig. 1)–the first computer based on vacuum tubes. It is estimated to have performed more calculations in a decade than the entire humanity had performed previously.[1] It took the next 10 years to construct the IBM 305 RAMAC (Fig. 1), the ton weighing machine that could store a little less than 5 MB of information.[1] Just to remember, it had 3000 to 6000 times lower capacity than the present-day USB storage device which can be found in almost everyone's pockets, or integrated into the new models of mobile phones. Integration of transistors into computing and communication machines strongly enhanced communication; in 1969, the first internet connection was created; 2 years later, the first e-mail message was sent.[3] Thus, the internet era can be said to have dawned 42 years ago. However, communicating machines were still too large in size and not practical for mass usage.

The next big step was the development of micro-processors; putting the computer on desks (in 1977); introduction of the first IBM PC; the creation of the portable PC (in 1981) (Fig. 1).[1] With all this, the computing power and access to information was made available to individuals, although it was confined to business activities for yet another decade.

The next big step took place only 23 years ago (in 1990), when the first web page was created.[1] This was a time when our master-degree students were born. Three years later, the Mosaic opened up the Web, which was then followed by exponential development of the web page phenomenon, first individually, and with introduction of Wikimedia in 2001 (just 12 years ago)[4] through collaborative development of the content and generation of knowledge (Fig. 1). Today, Wikipedia includes over 25 million freely usable articles written by over 38 million contributors worldwide.[4] The formation of WiFi Alliance in 1999[5] enabled massive exchange of data wirelessly and dramatically opened the access to the content, including the possibilities of content generation, which was no longer fixed to the wire. This fostered rapid expansion of mobile tools. The expansion of the content (knowledge) fostered development of Web search engines for rapid accessing of the content (Fig. 1), such as Yahoo in 1995 and Google in 1998,[6] and online service for peer-to-peer file sharing, such as Napster in 1999 enabling collaborative access to music, dramatically changed the media industry.[7] These tools changed the paradigm: information and knowledge were no longer sustained in storages available only to scholars, but became reachable by any individual equipped with appropriate tools.

Plethora of information, content and communication requirement stimulated enormous development of tools for mobile communication and access to the content (Fig. 1). Just 8 years ago (in 2005), the YouTube was introduced; hence, much information, including music, media, daily life, experiences etc. became available in video form.[8] Today, more than 72 hours of video material is being uploaded to YouTube every minute and 145 millions of hours of video material is being watched daily on YouTube, two-thirds of that outside USA.[8] The number of people accessing and generating the content is increasing exponentially, with estimation of almost 2.4 billion.[9] These brains and fingers

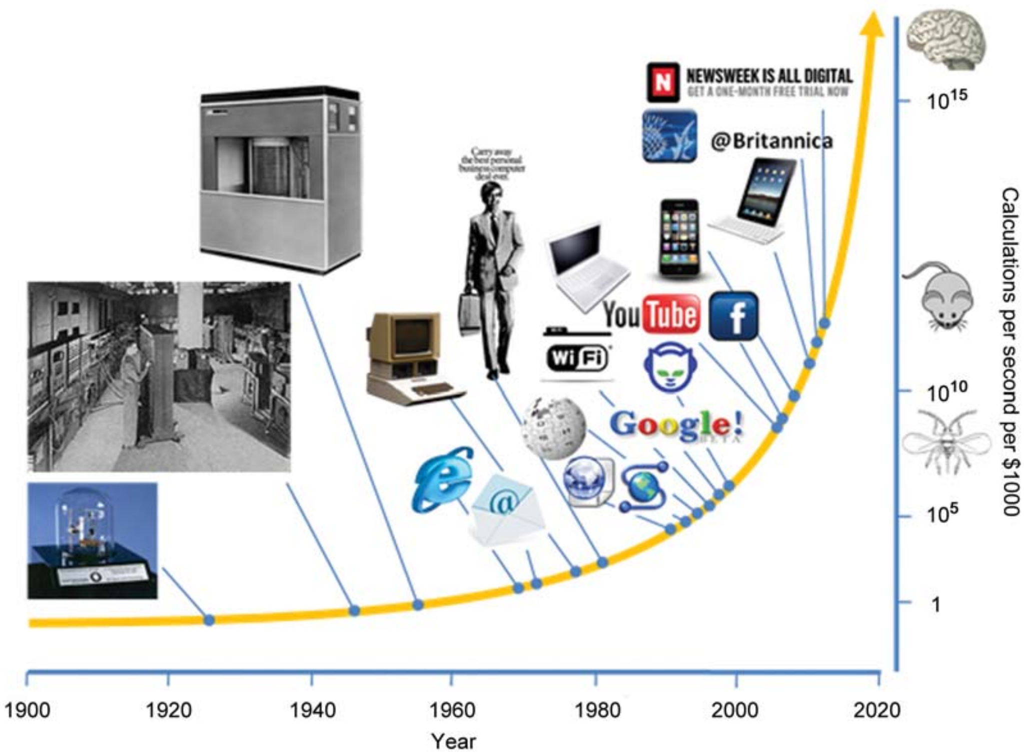

Fig. 1: Some important events in the development of information and communication technologies over the last century

are constantly connected and in effect, they generate and/or exchange knowledge all the time. This is also associated with the new paradigms of social evolution, including the development of new social networks (Fig. 1). The most popular one, the Facebook, was made available to everyone just 7 years ago, [10] presently connecting almost 1 billion people.[11] Needles to say, all this changes both human attitudes and values, profoundly affecting the social sphere. The effects and the consequences, however, are not being properly studied and estimated.

The iPhone was introduced 5 years ago (Fig. 1), making way for the boom of smart phones and tablets (just 3 years ago launched by Apple),[12] and this yet again dramatically increased the mobility to information and knowledge. With this and with the dramatic increase of wireless speed (1 Gbs is under experimentation)[13] the world took a dramatic turn, and no less–the world of learning. The symptoms of the new era of learning were apparent a year ago (March 13, 2012) when the *Encyclopaedia Britannica*, after 244 years, renounced any further print edition,[14] and when the *Newsweek*, only a few months ago, went completely digital[15] (Fig. 1).

Exponential Times

The above short timeline of turning points in the world of information access clearly reveals that we are experiencing constant acceleration of change. Similar developments, although not with the same speed, are also occurring in many other human activities. Thus, one should be aware that the speed and nature of technological change causes acceleration of social evolution and that many aspects are not synchronized but require systematic adaptation of societies, which puts enormous responsibilities on the decision makers and leaders of societies and institutions.

When trend projections are discussed and analyzed, especially when new technologies and global changes are considered, a rather poor way of thinking about the future often surfaces. A linear way of trend extrapolation is often used: for example, if something grew by 5% annually in the last couple of years, further growth of 5% in the following years is foreseen. When growth takes place in a linear fashion, it can be said to be predictable: in 10 years that value is going to be 10 times bigger (Fig. 1). However, when the value observed is exponentially doubling, it is going to be 1,000 times as big over a period of 10 years. In case of its exponential tripling, over 10 years it is going to be 60,000 times as big (Fig. 2).

In order to understand the impact of information and communication technology development on social evolution, it is essential to understand some processes that have already been proven. Moore's law says that the technological processing power and speed now doubling every 12 months while during the same time it declines in value by 50% (a factor of 4 every 12 months).[16] Some

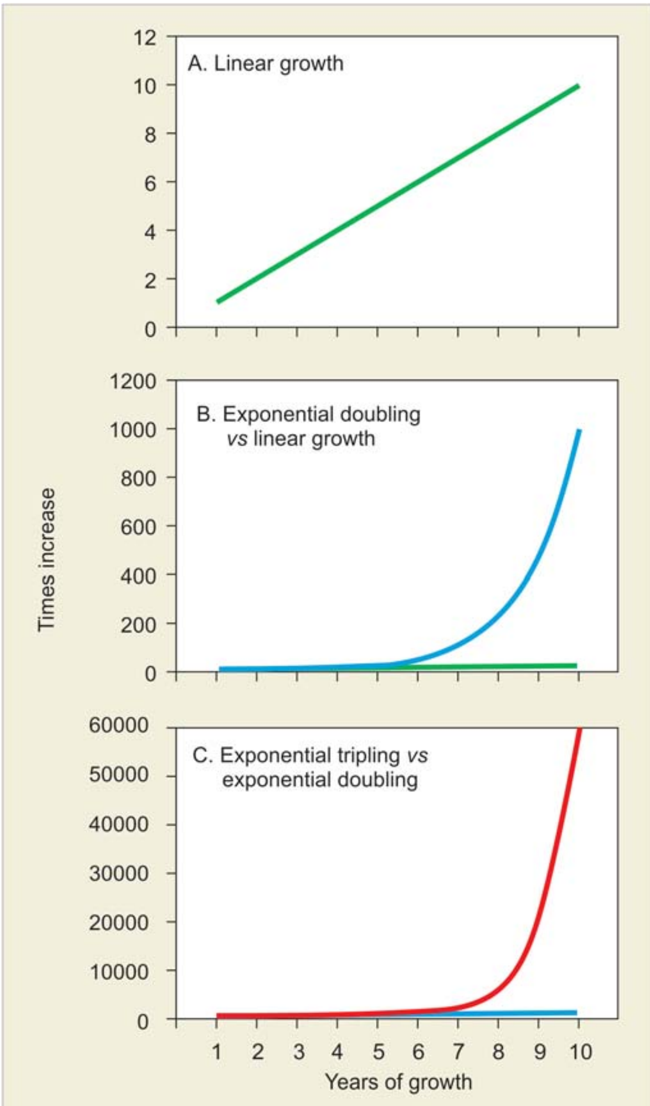

Fig. 2: Schematic representation and comparison of the linear growth with annual exponential doubling and tripling

researchers suggest that now, as nanotechnology has become reality, the processing power will be doubling every 6 months.[17] Gilder's law of the photon suggests that the bandwidth speed and capacity per dollar tripling exponentially every 6 months (a factor of 6 per year).[16] The number of web pages is doubling exponentially three times a year (a factor of 8).[18] As a result of these three developments, a huge number of brains are exposed to knowledge and internet is becoming the world's meeting house, a modern planetary forum, where millions distribute gigabytes of data.[19] The world is entering into the Age of InfoWhelm,[20] the age of exponential growth of information and exponential exposure of the human brain to information. In order to survive, to be able to process and to select huge amount of information, the human brain should also increase its processing power. In other words, the human brain should adapt to these changes.

Adaptation Capacity of Human Brains (Neuroplasticity)

There have been many discussions in recent years on the topic of adaptation of the human brain to all changes that are rapidly penetrating into our lives. These discussions are facilitated by the new discoveries in neuroscience in the field known as neuroplasticity. Although recent discoveries provide some new insights, we can say that very little is known. The puzzle is still not unveiled but evidence is also rapidly growing. In this chapter we will present some evidence that indicates aspects of adaptation of human brains to InfoWhelm.

Neuroplasticity represents the life-long capacity of the brain to change the neural pathways and synapses under the influence of external stimulation: by environmental influences and behavior, internal neural activity or reparation after brain injury.[21] In course of the last 2 decades, the 20th century view that the adult brain, upon completion of the development during childhood, has very little capacity for change has been replaced by the view that the brain has a life-long ability to adapt under environmental influences.[21] Within the rapidly growing field of neuroscience it is especially interesting to analyze the existing data related to cellular changes and to the cortical remapping due to learning. The phenomenon of adult brain adaptability to external stimuli become apparent through the discoveries showing that the visual and sensory pathways were fixed after the critical period of development,[22] and that the environmental influence could in fact modify connections between the neurons in the brain.[23] We now have abundant evidence demonstrating that the neural activation pattern in the lower part of the neocortex can change under environmental influences.[24] Current neuroplasticity research indicates that experience can change the physical structures and functional organization of the brain,[24] and that our ability to learn and form new memories is fully dependent on the brain's ability to be plastic—that is to change and adapt along with the acquisition of new experience and under the influence of the new environments.[25]

Even thinking, itself, can change the brain.[26] The best example is perhaps that which comes from the studies on Buddhist monks, the 'Olympic athletes' of mental training. Some monks have spent more than 10,000 hours of their lives in meditation.[26] Several studies linked short-term and long-term meditation practice with changes in the physical structure of the brain, such as increased cortical thickness or density of the gray matter,[27] and functional changes including different levels of brain activity.[28] Long-term meditators have larger 'folding' of the brain cortex (gyrification) than people who do not meditate,[29] which may be associated with the higher processing power of the brain.

Intensive neuroscience research recently provided many mechanistic explanations of the brain function and some general concepts arising from the collected experimental evidence. Generally speaking, it could be said that the basic directions for neurons between the basic functional areas in the brain are determined by genes and that they are established during the period of early childhood, to act as 'highways' that connect major functional areas of the brain.[30] Within these areas, a much more dense and complex network of interconnections, including also a huge number of synapses within a neuron, also pertains to the early brain development.[30] However, these connections are constantly being remodelled under environmental influences throughout the human life–like a complex network of side roads that are always under construction.[30,31]

How does it work? Recent research is getting insight into mechanistic explanations at the cellular level. The basis for all these changes is the remodelling of synapses. At birth, each neuron has ~2,500 synapses; during early childhood (i.e. in 3 years old children) the number of synapses per neuron rapidly increases to ~15,000 per neuron; later, in adults, it scales down to ~7,000.[32] As we get older, old connections get deleted as a result of a process called synaptic pruning[32] and new ones are formed under environmental influences, which takes place in course of a process which we call learning. Old synapses are cut and new ones are constructed. Thus, the external stimulation provides incentive to the formation of new synapses.[30-32] Scientists recently reported that the people who welcome new experiences develop stronger connections between their brain centres associated with memory, than the people who avoid experiencing anything new.[33,34]

Of course, the story is more complex. It is not only about numbers of neurons and synapses but also about the process of strengthening neural connectivity, known as long term potentiation[32] or activity-dependent plasticity, associated with the activation of synapses. This is very important for learning and understanding new thoughts. Existing evidence suggests that these complex events are based on upregulation and downregulation of more than 40 proteins which are operated within synapses. These can be proteins that enhance connections between neurons, functioning as channels and receptors or regulating receptor activities.[35-39] For example, a recent study from the McGill University reveals that the plasticity of nerve cell connections in the brain is regulated by a receptor that maintains proper synapse morphology and shape.[39]

The plasticity is essential for the learning processes that take place in the brain. 'It helps you to organize, keep or even to forget contents in a positive sense, to gain room for new inputs'–explains neuroscientist Nora Prochnow.[40] Every input, every thought, reshapes the brain. The brain operates in use-it-or-lose-it fashion: 'like sand on a beach, the brain bears the footprints of the decisions we have made, the skills we have learned, and the actions we have taken'.[41] For example, the study of a research group from the University of Bochum showed that the mice without pannexin 1, a channel protein, in memory-related brain structures displayed symptoms similar to autism and that their nerve cells lacked ability to form new synaptic contacts or give up old contacts based on the level of usage.[38,40] The cell communication in general was increased to such an extent that a further increase through the learning of new knowledge was no longer possible.[38,40]

It takes a lot to make a memory: new proteins have to be synthesized and neuron structures altered.[42] The majority of these memory-building mechanisms are not well understood, although some of them are known, and it is still a big question how all these mechanisms are regulated.[42] It seems that the balance of expression of small RNA molecules, known as microRNAs, controls neuronal protein production and thereby plays an important role in memory formation.[42] Recent advancement of the microarray techniques of rapid large scale genetic testing enabled analysis of microRNAs in the brain and demonstrated that that more than half of all known microRNAs are expressed in the amygdala.[42,43] Seven of those microRNAs increased and 32 decreased when learning occurred. One of them, miR-182, had one of the lowest levels and decreased further with learning and its overexpression prevented the formation of memory by decreasing proteins that regulate neuronal plasticity.[42,43] Apparently miR-182 could be a viable target for drug discovery.

Researchers in the field of neuroplasticity are very enthusiastic regarding its impact on education and also on the quality of life. Michael Merzenich, one of the pioneers of neuroplasticity, believes that 'brain exercises may be as useful as drugs to treat diseases as severe as schizophrenia–that plasticity exists from cradle to the grave, and that radical improvements in cognitive functioning–how we learn, think, perceive, and remember are possible even in the elderly'.[44] A recent study suggests that people with active cognitive lifestyles, i.e. those who are more mentally active, run a lower risk to develop dementia.[45]

What is a Critical Period for Adaptation?

It has been known for a long time that the critical period of human brain development is in early childhood and adolescence, a time when neural connectivity is most intensive, when the major pathways are under construction.

This is a time when environmental influences have enormous impact on their construction. At that time, the majority of children develop social contacts through their family environment, media exposure or, at least in Western societies, through interactions in kindergartens or schools. Thus, these inputs have enormous impact on the development of brain plasticity, and vice versa: changes in neuroplasticity may augment human intelligence, a process known as malleability of intelligence.[46] Therefore, within the framework of discussion on a new world of learning, it is of special interest to discuss the impact of the InfoWhelm era on the development of children's brains and the role of educational system in this context.

Altogether, it is important to keep in mind that children begin to show signs of higher level thinking skills as young as at the age of 4½, which is a critical period during which the nervous system responds very sensitively to the effects of experience.[47] Recent studies confirmed that there is a strong relationship between high scores among children who, as preschoolers, had strong vocabularies and were good at monitoring and controlling their responses, to their later ability to solve tests or understand analogies.[47] A young brain is very dynamic and flexible in strengthening certain connections and, at the same time, in weakening other connections, in order to get rid of the noise or less useful information, to make new memories.[48,49]

Usually, human intellectual capacity is estimated by the intelligence quotient (IQ), a standardized measure that takes into account a wide range of cognitive skills. Although it cannot precisely predict successful personal and social life, it was generally considered to be stable across the lifespan, and scores at one time point are often used to predict educational achievement and employment prospects in later years.[50] Generally, it is not clearly distinguished between the impact of the genetic makeup and the adaptation (learning) throughout the life on the development of intelligence. Recently, a group of scientists,[50] by using a combination of structural and functional imaging, showed that the verbal and the nonverbal IQ can rise or fall in the teenage years, the changes in performance validated by their close correlation with changes in local brain structure. In other words, they demonstrated that an individual's intellectual capacity is closely linked to the sensorimotor skills involved in learning, and can decrease or increase in the teenage years. This would be encouraging to those whose intellectual potential may improve, and would be a warning that early achievers may not maintain their potential. However, this would also be a warning for all those who are involved in planning and conducting of the organized learning process, especially for teachers. In addition, it would be essential to understand how the human brain responds to the digital age.

In conclusion, very little is known about the impact of exposure to media and digital content on the development of intellectual potential, especially when it comes to social skills. This topic should be, and we believe it will be, under extensive research in the following years. This research is especially required in order to understand the role of education.

Does the Human Brain adapt to the Digital Era?

One can expect that the constant exposure to media and information should elicit the neuroplastic response of human brain, both during the critical period and during old age. In the shaping of a new world of learning it is of primary importance to understand these processes which would enable proper adjustment of the formal educational system to the needs of new generations of learners and the adjustment of the nonformal learning processes to the needs of previous generations, also taking into consideration the aspect of informal learning.

A study by Prensky,[51] carried out 10 years ago, demonstrated that 10 years old, at that point in time, could expect, in the coming 15 years, to spend 10,000 hours playing video games, to send 200,000 e-mails, to spend 20,000 hours watching TV, and to spend 10,000 hours on their mobile phones, but also to spend less than 5,000 hours reading books. Thus, it is reasonable to believe that the large exposure to media, similar to long-lasting mental training, would physically and functionally change the brain. Digital natives—young people born into a world of laptops and cell phones, text messaging and twittering—spend an average of 8.5 hours each day exposed to digital technology.[52,53]

There is already evidence that searching the internet dramatically engages brain's neural networks, much more than book reading. Functional magnetic resonance imaging (fMRI) study of computersavvy middle-aged and older adults searching internet revealed that the internet search triggers key centers in the brain that control decision-making and complex reasoning.[54] Thus, it would not be a big surprize that dramatic (exponential) increase in environmental inputs to human brain in the wired society we are living now would change the ways in which the brain works, especially if compared to the brains of those who lived 50, 100 or 2000 years ago. This is associated with the dramatic increase of the amount of information to which the human brain is nowadays exposed.[55] Thanks to the exponential increase of broadband speeds and accessibility of devices that allow access to information (TV, radio, computers, smart phones, tablets and other), 'today's brain is exposed and adapted to channel more information in an afternoon than was stored in the fabled repository of the knowledge in the ancient world, the Library of Alexandria'.[19] With a click one can access Shakespeare's or Homer's writing, Brahms Hungarian dances or Monet paintings. Clearly, it is questionable whether under such exposure to the information the today's brain responds as the brains, i.e. 100 ago. This exposure is rewiring the brain's neural circuits, heightening skills like multitasking, complex reasoning and decision-making, but there is a concern that as a downside it diminishes 'people' skills, including important emotional aptitudes like empathy[56,57] and that with inevitable multitasking we are trading quality for quantity.[58] It seems that 'as the brain evolves and shifts its focus toward new technological skills, it drifts away from fundamental social skills'.[57]

We are bombarded with enormous amounts of data which are constantly being processed by our brains in order to create a coherent picture of our world. That picture is shaped from many diverse sources, such as radio news, TV, e-mails, texts, SMS, tweets, FB, billboards, PPT slides from in-person meetings... The messages and communication is spread across multiple media platforms. We are living in a transmedia world and transmedia storytelling is becoming a new platform and the new standard of the 21st century communication.[59] The complex concept which is emerging, already in use in entertainment and marketing, is underway to be used for social changes and, therefore, should also be used in educational system. Namely, storytelling speaks to all levels of the brain and it seems that stories are the way how the brain organizes information in order to rise above the noise which is already enormous.[59] Stories package information for rapid comprehension by engaging the brain at all levels: intuitive, emotional, rational and somatic.[59] Actually, the dilemma is rather old. Socrates himself feared that writing, the oldest information-technology of all, might end up making us less intelligent, with reading substituting for remembering.[59] People were worried about books, television, telephone as today they are concerned about internet–everything that disrupts the way people live and introduces change seems to have been a source of worry, at all times in human history.[60]

In addition to an optimistic view on human brain adaptation, there is also serious discussion regarding the dark side of it all, expressed by the view that internet teaches us to stop thinking![61] It can be said to develop inability to concentrate on anything for more than a few moments at a time. In addition, the rapid expansion of cloud technology brings about many additional questions, including, such as are we 'outsourcing our brains to the cloud?'[62] Bill Keller argues that when we outsource our memory to a machine, we also outsource an important part of our intellect and even identity.[62] All these questions arose in a public debate and, certainly, require serious research and scientific validation. However, in spite of the lack of justification by scientific methods, it is clear that we need to think 'scientifically' in order to survive the modern age, to be able to put things into categories, to operate machines, to think in a non-linear fashion and use modern technoloy.[19]

Are New Generations Different?

It is clear that generations of people differ in many aspects, especially in values and learning needs (Fig. 3). Exponential development of communication and access to information require accelerated development of instruments and methodology to study the new generations of people that grew with the InfoWhelm. This research is required for understanding not only the development of societies, political systems, society values or market trends, but also for the understanding of the development of learning requirements and, hence, the actual adaptation to learning

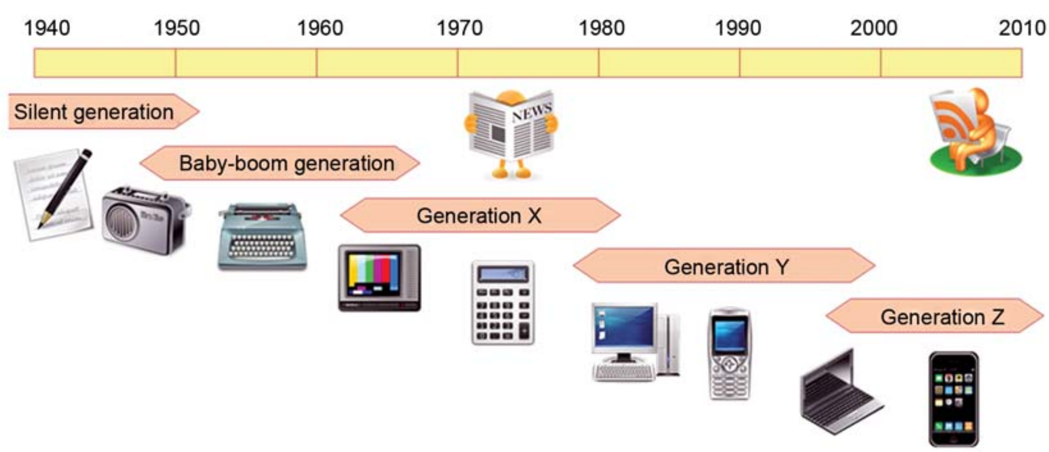

Fig. 3: Timeline of generations in the Western societies and tools as these generations are used for communication and access to information

environments and educational system. We will therefore briefly analyze the current understanding of the trends in relation to the learning development.

Although there is no clear consensus on the topic of generations, there are a number studies and books describing generation patterns, at least in Western societies.[63-69] According to the Strauss-Howe generational theory, each generation has common characteristics that give it a specific character.[63] For simplicity, we will refer to the classification based on the usage of contemporary technology for access to information and for communication. Although, this classification is based on the analysis (Fig. 3) of the American society, similar observations could also apply to other societies in the Western world, especially when it comes to the new generations living in the globalized world.[63,65] A silent generation was born between 1925 and 1942, during the Great Depression and the Second World War. They grew writing letters, reading books and newspapers, which were their principal ways to exchange information (Fig. 1). The baby boom generation was born during the baby boom period 1943 to 1964, and this was a generation associated with the rejection or redefinition of traditional values. This generation grew with the development of mass media and mechanical machines for the massive distribution of information (Fig. 3). The generation X (Gen X) followed the baby boom generation, a cohort born from the early 1960s to the early 1980s, shortly before, during and after the introduction of computers and the development of the digital technology (Fig. 3). The generation Y (Gen Y) was the following, born between early 1980s and late 1990s, associated with a marked increase in familiarity with communication, media, and digital technologies (Fig. 3). The generation Z (Gen Z) includes all those born after 1997 to the present day, usually named 'digital natives' thanks to being highly 'connected' and heavily involved in the use of communication tools and media technology (Fig. 3).

The first generation to face possibilities of rapid access to information during their education was the GenY, i.e. people born after 1983.[63,65,66] This generation was exposed to various information access tools and to the process of exponential expansion of the internet at the time of their primary or secondary schooling. They were faced with the fact that there is an easy access to information, but also a growing gap between the information tools and the body of information that constitutes the actual educational content provided in schools. This generation was exposed via fixed stations and screens of their computers. Thanks to the rapid expansion of WiFi technology, the generation born after 2000s was the one to be directly immersed into processes of intensive communication with access to all kinds of media via their mobile devices. They are intensively using technology most of the day.

The generation born after 1997 (Gen Z),[66] grew up within a highly sophisticated media and internet environment.[67] This generation is more internet savvy than the Gen Y. They are highly 'connected' and from the 'beginning' of their lives they would have been actively using communication and media technology. They were born into the world of World Wide Web, MP3 players, mobile phones, instant messaging and social networks. They are usually called referred to as the digital natives.[18, 63-68] Although we know a lot about the environment they grew up in, we actually have very little research-based information about the Z generation.

The generation born in the last decade of the 20th century already showed some characteristics that attracted attention and challenged intensive discussions about changes necessary in the educational system in order to respond to the needs of these people.[63,64,68-70] These characteristics were ascribed as Homo Zappiens generation, the term used by Dutch scientist Wim Veen.[69,70] Homo Zappiens plays games, communicates 24 hours a day, 7 days a week, sends messages via SMS, MSN, chat rooms, maintains constant connection to Facebook, integrating f2f and virtual friends.[69] A member of this generation never read a manual and they are not interested in technology behind.[69] For this generation, learning is playing. Communicating tools are used for controlling the flow of information, for struggling with an enormous quantity of information and for fast and appropriate selection of information according to their needs.[69] Actually, these 'new' brains are responding to enormous inputs, and the neuroplastic reaction should not be surprising. 'The skills screenagers develop while scanning computers screens, zapping the TV channels, 'criss-cross reading' texts, and thus rapidly processing huge amounts of information, will guarantee the survival of our civilization in the 21st century.'[66] They are developing an apparent capacity to process discontinued information, along with skills to construct meaningful knowledge from discontinued audio-visual and textual information flows (Fig. 4).[69]

Nonlinear learning capacity (Fig. 5) is associated with a clearly developed capacity of multitasking, an obvious characteristic of late Gen Y and Gen Z, described in many public discussions.[63,69,70] This capacity was associated with many alterations observed in schools, such as the inability to concentrate, etc. Although many teachers and parents discuss this capacity with deep concern, many experts suggest that the capacity of multitasking is a skill evolved

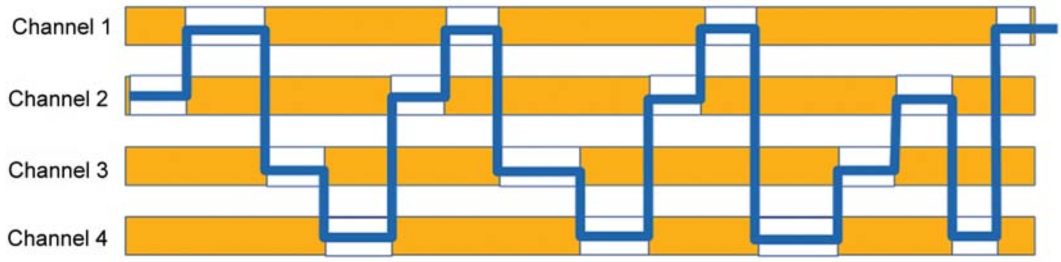

Fig. 4: Nonlinear learning skill developed by constructing the knowledge from different audiovisual sources

to survive the information burden,[68,69] being an apparent evidence of neuroplastic adaptation to simultaneous exposure to information from various sources, and that this skill evolves into an enhanced capacity of nonlinear learning (Fig. 5). The nonlinear learning skill is in apparent conflict with linear learning strategies used by schools and teachers who are usually baby boomers or GenXers–a way of learning developed through the educational system at their time of schooling. It can be easily recognized that linear learning could be as frustrating for GenYers or GenZers as the nonlinear ways of learning would be for baby boomers or GenXers. Thus, the nonlinear learning strategies demand a redesign of content, learning assets, objects to be accessed just-in-time.[68] In other words, it requires changes in the educational system.

Considering that the learning circuits of most of baby boom or GenX teachers are constructed by linear learning strategies, their capacity to implement nonlinear learning strategies in order to respond to the new needs is questionable. Although numerous policy makers and learning experts react to this problem with a resigned attitude, the battle should not be considered lost if it is true that the human brain can adapt similarly at a later age as well. GenYers and GenXers rivals when it comes to using mobile technology for social activities[57] and the same patterns adaptation of older 'novice' users of Google was observed, much like the brains of experienced Web users after just a few days.[57]

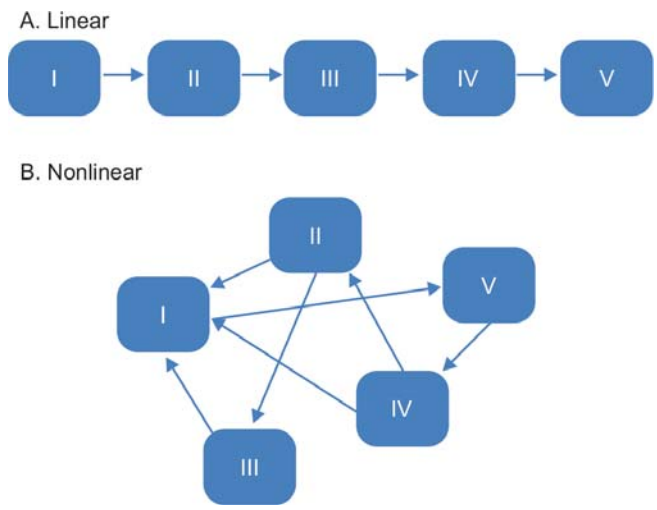

Fig. 5: Linear and nonlinear learning strategies

How should the Educational System respond to all these Changes?

Phenomena, such as the exponential growth of knowledge, instant information access, accelerated replacement of employment requirements, and nonlinear learning skills and values developed by new generations of students, can be said to bring about the need for continuous adaptation of the educational system and learning environments. The traditional school, conceived more than a century ago for the needs of the industrial society, no longer provides learning conditions that fit the needs of new generations of learners.

Learning contents in schools should be more flexible because content is nowadays available everywhere. By a single click, a student of the new generation is able to approach practically any information; 5 years ago this would have been possible through the use of a computer, but presently the task is made even easier thanks to the fast and easily portable devices that all students have in their pockets, smart phones or tablets; in the near future, even higher levels of immediacy are likely to evolve, maybe through the use of glasses, lenses or holographic 3D displays.[71-73] High quality easy to access visual content is replacing traditional books[74] and, therefore, the learning process in schools should be adjusted to the new sources. Therefore, traditional curricula should be replaced with learning goals.[75] Curricula makers therefore need to conceptualize the core subjects in ways which will transform the organized learning time in accordance with the needs of the 21st century learners. Apparently, traditional core subjects should be shrunk in order to free a substantial amount of time for the development of learning skills, for learning the content adapted to the 21st century's conceptual framework, and for using the 21st century tools within the 21st century learning context.[76] As Alvin Toffler says, 'The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn'.[77] In addition, assessment tools and evaluation strategies need to be adjusted.

Learning models should also be adjusted. Teachers are still directing the learning process in accordance with the 'sage on the stage' concept,[78] and this concept is no longer able to wrap up all needs of the new learners. It should be replaced by new models which include either community led learning or even learner led learning.[78] On both agendas, the role of the teacher is needs to become more focused on providing guidance on the side and information management,[78] since, the teacher ceases to be the only content provider.

New content and learning model requirements also require more flexibility in the organization of teaching, including flexibility in time and space.[78] The traditional framework based on providing 6 lessons a day, each lasting 45 minutes in course of 40 weeks cannot accommodate the new demands.[68] More flexibility in scheduling is required, including adjustments of the time slots according to the need of subjects, more individual and/or group working should be introduced, and communication in the classroom should be combined with the communication based on the use of new communication technologies and social networking tools.[68]

Finally, it is clear that the learning process should be planned as a lifelong need, which is in the domain of public responsibility. The entire educational system needs to be adjusted in order to accommodate the lifelong learning needs of citizens. The system of qualifications should be flexible enough to allow multiple paths in their achievement and upgrading throughout any persons' life. The need for lifelong learning is poses a challenge to traditional providers of educational services. New providers are invading the education service sector, from nontraditional providers that wrapping up such service into traditional forms, to many nontraditional providers that are using internet-based tools or even TV programs. Once the network of nontraditional learning providers expands sufficiently, the whole system of qualifications will be challenged and universities and schools will lose their primacy in providing educational services if they lose pace with innovative an inclusive trends, adapted to the needs of citizens.

CONCLUSION

The aim of this paper was to raise attention of medical professionals who are in charge of education that we are living in exponential times, that our brains are adapting to exponential realities, that the educational system is a tool for systematic development of opportunities both for individuals and for societies, and that the central role of the 21st century teacher is to connect brains. Today's schools and universities can still be said to function in an analog fashion whereas our students have gone digital. Currently, the educational system does not recognize skills of new generations and does not respond to their needs.

Our intention was not to present a detailed overview of the existing studies in the specific field but rather to stimulate discussion within the education-committed medical profession and to open the door to flexible thinking about changes in the world of learning. It is clear that a lot of research needs to be carried out before we can fully understand the intricate relations between the biological and social aspects of evolution, especially the ways in which they cause adaptation of the human brain to the wired world, the overall process of learning in the digital era, organization of learning environments and spaces, and organization of the entire educational system. New aspects of social evolution suggest that we should also think not only of learning skills during education but also need to focus on social skills. These skills should be integrated into all processes of learning, from preschool education to lifelong learning. As Alvin Toffler says (1998), 'Society needs people who take care of the elderly and who know how to be compassionate and honest. Society needs people who work in hospitals. Society needs all kinds of skills that are not just cognitive; they are emotional, they are affectional. You can not run the society on data and computers alone.'

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