Vol 5 | Issue 1 | Pages 205-210

Annals of Cognitive Science
ISSN: 2642-4290

Research Paper

DOI: 10.36959/447/352

Hopes for The Future of Humanity

*Krystyna C Laycraft**

The Center for CHAOS Studies, 4352 Salmon River Road, Armstrong, BC, Canada

Abstract

In this article, we present decisions and actions of people, who gave an enormous hope for the future of humanity and protection against Covid-19. Then we introduce the model of decision-making and discuss the concepts of responsiveness and decisiveness, which are interconnected with empathy as the main energizer and motivator of human actions. Finally, we discuss the role of exaptation and collaboration in the success of developing vaccinations against Covid-19.

Keywords

Ugur Sahin, Ozlem Tureci, Covid-19 vaccination, Hope, Decision, Responsiveness, Decisiveness, Empathy, Anticipation, Surprise, Exaptation, Collaboration

Introduction

What makes hope such an intensive pleasure is the fact that the future, which we dispose of to our liking, appears to us at the same time under a multitude of forms, equally attractive and equally possible… The idea of the future, pregnant with infinity of possibilities, is thus more fruitful than the future itself, and this is why we find more charm in hope than in possession, in dreams than in reality [1].

- Henri Bergson

When we started working on this article (December 14, 2020), the first transportations of Covid-19 vaccines were arriving in Canada & USA. Medical workers and elderly people living in nursing homes were getting their first shots. These shots brought enormous hope to everybody. "We're injecting hope", "A shot of hope," "We have a glimmer of hope," "Hope on the horizon," "The technology of hope," - these were some headlines of articles published those days.

For Henri Bergson, the most influential philosopher at the turn of the twentieth century, hope is an "intensive pleasure" that relates us to the future "pregnant with infinity of possibilities." So, hope drives us forward and towards changes for the better. Hope allows us to find safety and security [2]. The purpose of our article is to introduce the people, who gave us hope and to analyze what decisive factors in their actions brought them to this enormous success of developing the COVID-19 vaccine.

This is a service for humanity and in the center of our hearts that we are able to help people. It is our goal and our vision to make this vaccination available in every region of our planet [3].

-Ugur Sahin

I think the noblest thing you can use science and technology for is to serve the people. [4]

-Ozlem Tureci

These are statements of the German-Turkish scientist couple - Drs. Ugur Sahin and Ozlem Tureci - who successfully developed the world's first effective coronavirus vaccine. Their innovative work gave an enormous hope for the future of humanity and protection against COVID-19, the most deadly virus of our century. The couple dedicated their lives to the field of oncology and infectious diseases and spent years pioneering personalized immunotherapy treatments for cancer. In 2008, Drs. Sahin and Tureci set up BioNTech in the central German city of Mainz and their main desire was to develop a cancer therapy for each individual patient. In order to develop such a therapeutic for cancer, their team, by combining ground-breaking research with cutting-edge technologies, has developed cancer mRNA technology. Dr. Sahin was recognized as an inventor and was invited to the World's Top 50 Innovators conference 2019, at the Royal Society, on 23-25 of September 2019, where he gave a lecture on "Individualized Cancer Immunotherapy" [5]. Later in response to a question from the audience, he explained

***Corresponding author:** Krystyna C Laycraft, The Center for CHAOS Studies, 4352 Salmon River Road, Armstrong, BC, Canada

Accepted: August 20, 2021

Published online: August 23, 2021

Citation: Laycraft KC (2021) Hopes for The Future of Humanity. Ann Cogn Sci 5(1):205-210

how his technology could be applied not only to cancer but also to infectious diseases and autoimmune conditions [6].

The Decision

The condition of a truly human existence is awareness of and choice of what is quintessential, unique, and enduring in a man, without which existence itself would be valueless [7].

-Paul Cienin

On Friday, January 24, 2020, Dr. Ugur Sahin read an article in the Lancet [8] about an outbreak of pneumonia of unknown cause, not only in China, but also in Thailand, Japan, Korea, the USA, Vietnam, and Singapore. The authors of this article recognized the challenge and concerns brought by this novel coronavirus to the world. They appealed to the scientific community, "Every effort should be given to understand and control this disease and the time to act is now" [8].

Dr. Sahin responded to this appeal immediately and very seriously. During that weekend, using the coronavirus' genetic sequence, published by Chinese researchers on January 11, he designed 10 different candidates of vaccination on his private computer. In other words, he was testing if he could repurpose the mRNA cancer technology into the future development of a vaccine against the coronavirus.

On the following Monday, Dr. Sahin was ready to make the final decision. He decided to refocus his company's research and concentrate on the development of a vaccine against COVID-19 by applying mRNA-based technology. He reorganized his staff into seven-day shifts, asked key workers to cancel their holidays, and concentrate completely on fighting the virus in order to develop a vaccine in months rather than years. The BioNTech Covid team was given the title "Project Light Speed" [9].

Not only did Dr. Sahin have a vast experience as a medical doctor of cancer patients and a deep knowledge of innovative cancer immunotherapy as a researcher, but he also had the collaboration and complete support of his scientist wife, Ozlem Tureci and thousands of scientists of his BioNTech Company as well as of other international scientific institutes. And all of them were behind Dr. Sahin's decision.

Dr. Sahin shared in one of the interview about the collaboration with his wife,

"*It really is a privilege to work together. You don't need to explain every day why you are doing things. Her office is just one door down so if I have a good idea, I go next door and we discuss it and we don't always have the same opinion*" [4].

On March 16/17 2020, their company BioNTech came to collaborate with the U.S. pharmaceutical company Pfizer in order to increase manufacturing capacity of COVID-19 vaccine. "Combatting the COVID-19 pandemic will require unprecedented collaboration like never before, " said Mikael Dolsten, Chief Scientific Officer and President, Worldwide Research, Development & Medical, Pfizer. "I am proud of Pfizer's collaboration with BioNTech and have every confidence in our ability to harness the power of science-together-to bring forth a potential vaccine that the world needs as quickly as possible" [10].

On November 9, 2020, Pfizer reported the vaccine to be more than 90% effective in preventing infection in volunteers. "Today is a great day for science and humanity. The first set of results from our Phase 3 COVID-19 vaccine trial provides the initial evidence of our vaccine's ability to prevent COVID-19, " said Dr. Albert Bourla, Pfizer Chairman and CEO. "We are reaching this critical milestone in our vaccine development program at a time when the world needs it most with infection rates setting new records, hospitals nearing over-capacity and economies struggling to reopen. With today's news, we are a significant step closer to providing people around the world with a much-needed breakthrough to help bring an end to this global health crisis" [11].

The Model of Decision-Making: The Route to Exaptation

In this section, we present the conceptual model of decision-making, which links the Plutchik's Psycho-Evolutionary Theory [12] with the idea of self-organization [13]. For Plutchik emotions are adaptive reactions to the basic problems in life. He introduced eight primary emotions that come in pairs of opposites-one for adapting to positive situations (opportunities) and one for negative, problematic situations (obstacles). The secondary and tertiary emotions emerge during the process of mental development, as primary emotions are combined into pairs and even triples [14]. These emotional experiences increase our flexibility and capacity to deal with complex and challenging problems.

The model of decision-making contains two tertiary emotions of *responsiveness*, and *decisiveness* that are interconnected by *empathy*. The main inspiration for creating this model was Dr. Sahin's decision. We examine what primary emotions and then secondary emotions are involved in the process of decision-making and what is their role in this process (Figure 1).

Responsiveness

Because we are fast we need to be even more diligent.

-Ugur Sahin

Responsiveness means to respond as quickly as possible to the experiencing unfortunate events or situations. Responsive

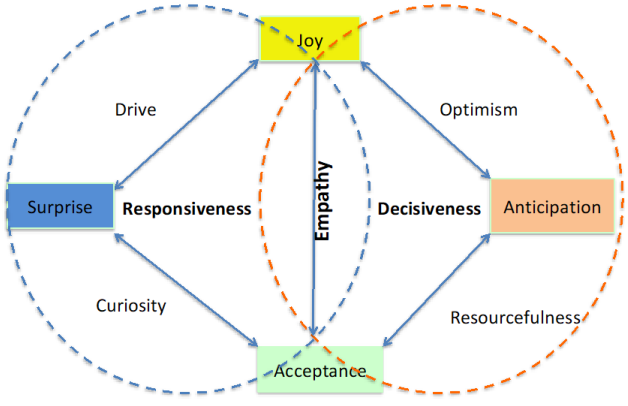

Figure 1: The model of decision-making.

people are in the state of being aware, attentive, and willing to act in a particular situation. The information about the deadly outbreak of pneumonia became the unfortunate event that had a stimulating influence on Dr. Sahin's mental state.

In our model, *responsiveness* emerges through the process of self-organization of *surprise*, *joy,* and *acceptance*. Surprise combining with acceptance creates *curiosity*, while surprise with joy creates an intensive feeling of *drive,* and finally acceptance with joy creates a strong emotion that can represent *love*, *friendliness,* and *empathy*. By linking secondary emotions with primary emotions, three definitions of responsiveness are proposed.

Responsiveness => curiosity & joy

I am driven by curiosity, I am always asking questions,

I want to understand how things work [4].

-Ugur Sahin

The first definition of responsiveness is a combination of curiosity with joy that expresses the intensive and focused desire to learn or to know about a novel, and unexpected event. Curiosity is the desire to voluntarily and intentionally accept, or incorporate that, which is new or unexpected, [12] while, joy is a source of energy that drives people to act. So, joy as a positive emotion, has a vital impact on people's social and cognitive behaviour such as openness to novel ventures, to novel interpersonal contacts, and to creative thinking [15].

As we see from Dr. Sahin's statement, he is driven by curiosity that serves to motivate him acquiring new knowledge and learning.

Responsiveness => empathy & surprise

I worked in a cancer hospital and I had to tell many patients that we couldn't help them anymore. As a scientist I know that we are doing everything that is possible we need to do more. That's what drives me on. [4]

-Ugur Sahin

The second definition of responsiveness is a combination of *empathy* with *surprise* that expresses the motivation for responding to the unfortunate event. Surprise prepares individuals to deal effectively with the new, sudden or unfortunate situation, while empathy evokes altruistic motivation that is linked with the goal of increasing another's welfare [16]. Dr. Sahin was not only curious and attentive, but because being compassionate and empathetic toward others, he responded quickly to their needs in order to restore their well-being.

Responsiveness => acceptance & **drive**

What drives us is the knowledge that there are kids who want to have a normal life, there's the mother, the teacher, the old person being isolated, there is much need [4]. - Ugur Sahin

Finally, the third definition of responsiveness is a combination of acceptance with drive that expresses the willingness to act in a way that is in agreement with the values and goals of the drive. It sets up a path for the future decision. *Drive* refers to arousal and internal motivation to reach a particular goal. There are many drives states besides hunger and sexual arousal that affect people on a daily basis. Drive states are rich in their diversity such as drive for achievement, activity, affection, curiosity, exploration, and many more [17]. By combining with acceptance, the drive state (the state of arousal) grows significantly and then people can respond to the situation more swiftly in agreement with their values and goals. Again, from Dr. Sahin's statement, we learn that his main drive for his response to work on the development of the vaccine is to help people in need and bring normality to their lives.

Decisiveness

Mr. Sahin inspired me from the very beginning. I think it is one of his strengths that he can get people excited about the cause [18].

-Andreas Kuhn

Decisiveness is the ability of the individual to engage in the decision-making process. Making decisions is recognized as one of the fundamental features of life. When a decision is made, some possibilities are realized and others eliminated. As possibilities are actualized, new life-patterns emerge [19].

A combination of the three emotions of *acceptance*, *anticipation* and *joy*, creates the secondary emotions of *resourcefulness* (acceptance & anticipation), *empathy* (acceptance & joy), and *optimism* /courage (anticipation & joy). By combining secondary emotions with primary ones, we proposed three definitions of decisiveness.

Decisiveness => resourcefulness & **joy**

This is an expertise, which makes it our duty to contribute now. *I think the noblest thing you can use science and technology for, is to serve the people* [4].

-Ozlem Tureci

The first definition of decisiveness is a combination of *resourcefulness* with *joy* that expresses the activation of internal resources such as critical and creative thinking, the abilities to apply knowledge, skills & experience, expertise, the collaboration skills, sensitivity, and adaptability, in order to achieve the future goals. Whereas, the main role of joy is to give people the vitality to press on toward their goals. Just after learning about the unknown disease, Dr. Sahin applied his knowledge and expertise in the mRNA technology and was able to design 10 different candidates of the vaccination on his private computer. So, his remarkable resourcefulness and strong energy pushed him to make a quick and firm decision.

Decisiveness => empathy & anticipation

Our desire to find a vaccine did not grow of any competitive, financial or scientific impetus, but because we felt a "moral" imperative to help the world.

-Ozlem Tureci

This is a service for humanity and in the center of our hearts that we are able to help people. It is our goal and our

vision to make this vaccination available in every region of our planet [3].

-Ugur Sahin

The second definition of decisiveness is a combination of *empathy* with *anticipation* that the empathic feelings towards others motivate the individual to make a decision in order to help people and bring normality and well-being in their future lives. Empathy is defined as a deepened feeling of sympathy toward other people, friendliness, understanding, and wish to assist them. [20] While, anticipatory thinking enables decision-makers to visualize courses of action and evaluate what sorts of problems they might lead to. It is essential for planning, and re-planning, for preparing to alter the direction already taken. This is exactly what motivated Dr Sahin and his wife Ozlem Tureci. They decided to refocus their company from the cancer research into the work on fighting a virus. They planned to develop a vaccine in months rather than years in order to save many lives. This is why; the BioNTech Covid team was given the title "Project Light Speed."

Decisiveness => acceptance & optimism

I accept things I cannot change, but I also try to concentrate with determination and courage on things that are within our sphere of influence, which is often greater than you first think [18].

-Ozlem Tureci

Finally, the third definition of decisiveness is a combination of *acceptance* with *optimism* that expresses *courage* to make responsible decisions. As Nicholas Murray Butler - an American philosopher and educator said, "Optimism is the foundation of courage and true progress." Optimism is the expectation that one's own outcomes will generally be positive. It incorporates a belief that a stressful present can change to become better in the future [21]. Acceptance is an intentionally open, receptive, and flexible attitude with respect to moment-to-moment experience [22]. Therefore, when acceptance is linked with optimism, optimistic people are able to generate a clear picture of what they want of the future and express a strong determination for accomplishing their goals. In the opinion of his coworkers, Dr. Sahin is a visionary leader who inspires and leads them in the direction of his vision.

The following statements demonstrate their opinions:

"Ugur is the visionary who shows us the future & Ozlem then tells us how to get there," [23] said Helmut Jeggele, BioNTech Supervisory Board Chairman.

"Mr. Sahin inspired me from the very beginning, I think it is one of his strengths that he can get people excited about the cause," [18] Andreas Kuhn, BioNTech's Senior Vice President of RNA biochemistry and manufacturing, said at the 2019 Mustafa Award ceremony.

Conclusion

We proposed that the process of decision-making is not a monolithic process but rather a set of different processes that are interrelated with each other. In our model, we recognized three processes. The main components of the first one are curiosity, resourcefulness, and joy. Curiosity is the main motivator for gaining new knowledge and learning, joy is the source of energy for being persistent, and resourcefulness is the energetic and creative movement of internal resources that can open the door to great innovation. Next, the second process contains drive, optimism, and acceptance. They express willingness to act in agreement with the chosen values and goals, and the courage and determination for accomplishment of these goals.

Finally, the third process contains surprise, empathy, and anticipation. Empathy plays a special role of bridging responsiveness with decisiveness. Empathy linked with surprise expresses the altruistic motivation to respond quickly to the unfortunate event, while empathy with anticipation motivates the individual to make a firm decision to bring well-being in people's future lives. So, empathy becomes the main energizer and motivator of human actions.

Next, we would like to point out the importance of surprise and anticipation in the process of decision-making. They both deal with the idea of *territoriality* introduced by Robert Plutchik in his Psycho-Evolutionary Theory. Territory doesn't have to only be in the sense of a physical area, but can be our internal world, our rationality, affects, beliefs, intuition and so on. Understanding what is our "territory" allows us to *anticipate* what happens around us, how to adjust present behaviour in order to address future problems, what decisions to take in the present according to forecasts about something that may eventually happen. However, the emotion of *surprise* is the opposite of anticipation, as it is outside our scope of familiar "territory." Surprise prepares us to deal effectively with a new and sudden situation and directs our attention to it. Surprise starts a learning process in which our "territory" may be extended or restructured. So, the process of decision-making can be understood as a transformation of consciousness to higher levels of awareness and understanding [24].

Exaptation as a creative breakthrough

Rediscovering a new function for something can be just as important as the discovery itself [25].

It was a fortunate coincidence that we were in a position to fight this disease. *We still believe it could revolutionise the entire industry* [26].

-Ozlem Tureci

In this section, we would like to concentrate on the substantial component of Dr. Sahin's decision. Dr. Sahin repurposed the mRNA cancer technology for the developing COVID-19 vaccination. This radical change in the function of his technology is an example of a relatively new concept of exaptation. Stephen Gould and Elisabeth Vrba - the American palaeontologists coined exaptation as a counterpart of the concept of adaptation. Exaptation describes a radical shift in the function of the specific trait during biological evolution [27]. The evolution of feathers is a classic example of exaptation. Feathers have initially evolved for thermal regulation (adaptation) but later were adapted for flight (exaptation).

Recently, the concept of exaptation has been applied to the study of technological innovation [28]. Technological innovations are often the result of co-opting existing technology to develop something new. For example, Corning Inc. used its longstanding expertise and innovations in glass technologies to produce research in fibre optics, which changed the world of telecommunications [29].

For instance, the laser (an acronym for light amplification by stimulated emission of radiation) was the result of fundamental scientific research, without a concrete application. Only later was the laser *exapted* into a diversity of applications, including microsurgery, holography, compact disc players, and many more.

Another example of exaptation is the compact disk, which was an adaptive design for solving the problem of poor quality of vinyl phonograph records by using light as a medium. However, CD-ROM technology was *exapted* for a data storage medium for computers that set the stage for the eventual commercialization of the technology in both the music and computing industries [28].

Many technological exaptations are the results of unique human capacity - the power to induce exaptation. "That is, unlike birds whose wings were co-opted for flight by chance, humans have the power to attribute new functionality to the technologies that they have played a role in creating" [30].

Based on our conceptual model, we propose that Dr. Sahin's deep curiosity and remarkable resourcefulness, combined with his internal vitality empower him to rediscover new functionality of the cancer mRNA technology to the development of COVID-19 vaccine. This creative breakthrough could "revolutionize a whole industry" as Dr. Tureci said in one of the interviews.

Collaborations

Collaboration has no hierarchy.

The Sun collaborates with soil to bring flowers on the earth.

-Amit Ray- a philosopher and spiritual mentor

The mental characteristics of Drs. Sahin and Tureci, such as curiosity, resourcefulness, empathy, enthusiasm, responsiveness, decisiveness, commitment, and visionary, are the vital elements of the *collaboration skills* that brought them to the real success of developing a vaccination against COVID-19.

Dr. Sahin explained that their enormous success was a result of a cosmopolitan collaboration,

"*In our company we have people from more than 60 countries; our meetings even though we are located in Germany are always in English. We have people from Asia, Africa, the United States, England, around Europe, Turkey. In science it does not matter where you are from, what counts is what you can do and what you are willing to do. This is a vaccine not only by Pfizer and Biontech, it is a vaccine by mankind because every single individual has their history and education. It just shows that if you are given a chance, everyone can contribute*" [4].

A group of people collaborating together in order to generate novel solutions in support of a shared vision and benefit from the interaction with each other can be understood as a complex adaptive system. An *adaptive complex system* is an open system, made up of numerous heterogeneous elements that interact with one another in a nonlinear way and that constitute a single, organized and dynamic entity, able to evolve and adapt to the environment [31].

A complex system operates under *far-from-equilibrium conditions*, in which a constant flow of energy and information links its components into more ordered patterns. The emerging patterns in turn influence the behaviour of the components of the system. As a result of this process, all individual coordinating components of the system no longer behave independently; the system generates something new: unexpected structures, patterns, and properties known as *emergence* [31].

The human brain is an example of a complex adaptive system in which single neurons interact in simple ways while their collective neural network produces highly complex properties such as creativity and consciousness. Creativity and consciousness are examples of emergence. As we learned from Dr. Sahin's statement, the BioNTech company contains a group of scientists from more than sixty countries that bring to the group their diverse skills, knowledge, experiences, beliefs, perspectives, creativity, and emotions. The diversity in an organization is very important. The greater diversity, the greater number of possibilities can be explored and the greater chance for novel solutions.

These diverse people were connected by a common goal and shared vision: "*We feel a duty to exploit our full technology and immunotherapy expertise to help address the COVID-19 pandemic emergency. Our aim is clear: Making a potential vaccine available to the public as quickly as possible-worldwide*" [32].

The goal of developing a vaccine against a deadly virus evoked in them the strong emotions of willingness, enthusiasm, and commitment. In this far-from-equilibrium emotional state, they organized themselves into the highly adaptable and resilient group. In the long run, by active interchanges of their ideas, knowledge, and skills, the innovative vaccine against COVID-19 has emerged. The vaccine as an emergence is not a fixed entity but it is a continually changing process. The scientists involved in the development of the vaccine are aware that it needs to be constantly adjusted to the COVID-19 situation worldwide. They have become enormously attentive in order to quickly react to the changes of the COVID-19 situation by modifying the vaccine and improving delivery methods. They feel moral responsibility for the lives of many people. This kind of responsibility expresses an authentic attitude that "has emotional and intellectual roots. It arises from emotional, intellectual, and imaginational excitability, from empathy and identification, from consciousness and self-consciousness, and from prospection." [20]

Final Note

In the final note, we have pointed out the importance of responsiveness, decisiveness, empathy, exaptation, and

collaboration in education. Responsiveness of educational professionals (e.g. teachers, instructors, and supervisors) is the fundamental component of their profession. They should be curious, attentive, and empathetic towards their students and respond to their students' educational needs. Their responsiveness brings them to the educational decisions of accepting students' viewpoints, ideas, creative and critical thinking, knowledge, and experiences. Therefore, by engaging in the collaborative interaction with their students, they help them to make their own educational decisions that transform their consciousness to higher levels of awareness and understanding.

Finally, exaptation as an important mechanism of novelty generation can have an application in education. Education can play a role of empowering people to rediscover new functionality of the existing technologies, theories, and capabilities and find novel and unexpected solutions. This functional shift can have a significant impact on new developmental processes in a variety of areas. For example, the concept of self-organization as the spontaneous emergence of new structure and new forms of behaviour in open, nonlinear, and complex physical or chemical systems has been exapted (co-opted) to psychology, personality development, adolescent development and creativity, brain development, and decision-making process [24].

References

1. Bergson H (1960) Time and Free Will. Harper & Brother, New York, 9-10.
2. Kast V (1991) Joy, inspiration, and hope. Texas A&M University Press College, USA, 136.
3. Pieltgen F (2020) US Covid-19 vaccine authorization is 'a most important milestone,' BioNTech CEO says.
4. Thomson A, Sylvester R (2020) The modern-day Curies: Meet the scientist couple behind 90% effective covid-19 vaccine.
5. World's Top 50 Innovators 2019, Royal Society, Future of Healthcare session (2019) Prof. Dr. Ugur Sahin, CEO, BioNtech. Individualized Cancer Immunotherapy.
6. (2020) Dr. Ugur Sahin discussed the versality of his mRNA-based technology.
7. Kazimierz Dabrowski (1972) Existential thoughts and aphorisms. Gryf Publications Ltd, London 11.
8. Wang CH, Horby PW, Hayden FG, et al. (2020) A novel coronavirus outbreak of global health concern, The Lancet 395: 470-473.
9. Neilson S (2020) The co-founder of BioNTech designed the coronavirus vaccine it made with Pfizer in just a few hours over a single day, Business Insider.
10. (2020) Pfizer and BioNTech announce further details on collaboration to accelerate global COVID-19 vaccine development, GlobeNewswire.
11. (2020) Pfizer and BioNTech announce vaccine candidate against COVID-19 achieved success in first interim analysis from phase 3 study.
12. Plutchik R (1980) Emotion, a psychoevolutionary synthesis. Harper & Row, New York.
13. Self-organization is an idea that explains the process of the spontaneous emergence of new structures and new forms of behaviour in open, nonlinear, and complex systems.
14. TenHouten WD (2008) A general theory of emotions and social life. Routledge, London& New York.
15. Isen AM (2004) Some perspectives on positive feelings and emotions: Positive affect facilitates thinking and problem solving. In: Manstead ARS, Frijda NH, Fisher A, Feelings and emotions: The Amsterdam Symposium. Cambridge University Press, Cambridge, England, 263-281.
16. Daniel BC, Naida A, Lishner DA, et al. (2002) Emapthy and altruism. In: Snyder CR, Lopez SJ, Handbook of Positive Psychology. Oxford University Press, 485-498.
17. Drive Theory. Psychology research and reference.
18. (2020) German researchers advance coronavirus vaccine.
19. Taylor MC (2003) The moment of complexity: Emerging network culture. The University of Chicago Press, Chicago, USA, 149.
20. Dąbrowski K, Kawczak A, Sochańska J (1973) The dynamics of concepts. Gryf Publications Ltd, London.
21. Chang EC, Yu EA, Lee JY, et al. (2013) An examination of optimism/pessimism and suicide risk in primary care patients: Does belief in a changeable future make a difference?. Cognit Ther Res 37: 796-804.
22. Hayes SC, Levin ME, Plumb-Vilardaga J, et al. (2013) Acceptance & commitment therapy and contextual behavioural science: Examining the progress of a distinctive model of behavioural & cognitive therapy. Behav Ther 44: 180-198.
23. Pancevski B (2020) How a couple's quest to cure cancer led to the West's first covid-19 vaccine. The Wall Street Journal.
24. Laycraft KC (2019) Decision-making as a self-organizing process. Ann Cogn Sci 3: 86-99.
25. Ferreira MR, Reisz N, Schueller W, et al. (2020) Quantifying exaptation in scienfic evolution. In: La Porta, Caterina, Zapperi, et al., Understanding innovation through exaptation. Springer Nature, The Frontiers Collection.
26. Miller J (2020) Inside the hunt for a Covid-19 vaccine: How BioNTech made the breakthrough. The Big Read.
27. Gould SJ, Vrba ES (1982) Exaptation-a missing term in the science of form. Paleobiology 8: 4-15.
28. Dew N, Sarasvathy SD, Venkataraman S (2004) The economic implications of exaptation. J Evol Econ 14: 69-84.
29. Watson P (2017) Convergence: The idea at the heart of science. Simon and Schuster, New York.
30. Garud R, Gehman J, Giuliani AP (2016) Technological exaptation: A narrative approach. Ind Corp Chang 25: 149-166.
31. Bertuglia CS, Vaio F (2005) Nonlinearity, chaos & complexity: The dynamics of natural and social systems. Oxford University Press, UK, 276.
32. Project-lightspeed.

DOI: 10.36959/447/352