Nanotechnology: Neuromarketing and the Use of Nanotechnology and its Potential

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Abstract. The purpose of the paper is to clarify the issues of nanotechnology, its origin, and its progress, as well as its use and importance in the future. The paper focuses on the potential use of nanotechnology in many directions, primarily in neuromarketing. Neuromarketing is an evolving field that studies the human brain, and consumer behavior and nanotechnology represent one of the possibilities for research and implementation of solutions in this field in the future. The combination of nanotechnologies and neuromarketing can create an area that offers new possibilities, scientific answers, and technological innovations that have not yet been identified. We created an online questionnaire to identify nanotechnology awareness in the Slovak republic.

Keywords: nanotechnology, neuromarketing, neuroscience, neuromarketing research

JEL classification: *M31, M39*

1 Introduction

Every single piece around us consists of atoms, which are not visible to the naked eye. Atoms are used by nanotechnology to research very small parts, and then in the application part, we use these small parts to solve specific problems. It's basically technology, engineering, and science at the same time. We can apply nanotechnology in various research areas such as physics, chemistry, biology, neuroscience, and the like. The beginnings of the nanometer were first described by Richard Zsigmondy, a Nobel laureate in the chemistry category when in 1925 he described and introduced nanometer terminology. He was the first to measure particle size. Specifically, he measured gold colloids using a special microscope (Hulla, JE, Sahu SC., 2015).

Several decades later, the mention of nanoscience and the use of nanotechnology took place at a conference in California in 1959. Physicist Richard Feynman described

how it was possible to manipulate and control individual atoms and the molecules themselves. The idea was developed ten years later and conditioned the emergence of the term nanotechnology. The name was used by Professor Norio Taniguchi in his study. In 1981, 22 years later, after Feynman's speech, nanotechnology itself began to be used. By using a modern tunneling microscope, it was able to examine individual atoms. We call it the beginnings of modern nanotechnology (NNI, 2022).

It is very difficult to realize how small the atoms and individual parts are. To clarify the problem, we are talking about one nanometer, which represents one billionth of a meter. In mathematical terms, it is 10^{-9} meters. For example, a thumb-sized object is 25,400,000 nanometers (NNI, 2022).

1.1 Nanotechnology

When we are talking about nanosciences, we can call it a sequence of phenomena and manipulation of materials on an atomic, molecular and macromolecular scale. Nanotechnologies are attracting great interest from investors around the world. Governments and. organizations set aside a huge amount of funding to fund such development and scientific research. On the other hand, we also know opponents who talk about nanotechnologies as not entirely safe industries. We include many industries and scientific disciplines in the category of nanotechnology where we use different procedures, materials, tools, devices, approaches, and the like. Nanotechnologies actually study very small parts and particles and break down the whole into miniature parts, which we then investigate. Thanks to new possibilities and technologies such as the tunneling microscope or the atomic microscope, nanoscience has moved to a very high level and has spread to various areas of our lives. We also use nanotechnology to create elements for computer chips. Computer chips and CD and DVD drives have been operating at the nano level for quite some time. The future of nanosciences will increasingly focus on shrinking individual parts and increasing storage capacity for computer chips and other technologies used in a wide range of electronics, the automotive industry, and so on.

The application of nanotechnology in medicine appears for a significant part of the overall use of nanotechnologies globally. Scientists and doctors can use nanotechnology to treat specific parts of the body where it is needed. This means that, for example, chemotherapy treatment is only possible locally at the designated site, not on the patient's entire body. Such a revolutionary possibility can improve the treatment itself and its course (Hays A. S, Robert J. S., 2013).

With research into central nervous system (CNSD) disorders, neuroscientists and scientists in the field of nanotechnology have found that by combining the concepts of neuroscience and nanotechnology, we can obtain much better results in the treatment of various disorders and diseases. Researchers agree that conventional methods, such as drug delivery, are not always sufficient. Using nanotechnology, scientists can apply ingredients that increase availability, increase the penetration of molecules and parts, and even with very low side effects. All these facts speak of great advances in

neuroscience and nanotechnology itself. Invasive procedures and applications of microchips are becoming interesting areas of neuroscience, nanotechnology, and neuromarketing as well as related areas of research. nano-devices directly into the body or brain (Cetin, M et al., 2012).

In the future, nanotechnologies are expected to enable more efficient approaches to production in any field, using less raw materials and energy. Most nanotechnologies are not expected to pose any new risks to humans or the environment. Concerns about the development of nanotechnologies are also conditioned by the fact that these are new technologies. Of course, the question arises as to who benefits most from the use of nanotechnologies, but it must not be forgotten that nanotechnologies should first and foremost solve problems (Dowling, Ann. P, 2004), (Ferreira, L. et al., 2008).

The combination of neuroscience and nanotechnology was revolutionary. The advancement of ever more sophisticated technology has resulted in many discoveries and scientific findings throughout neuroscience and the future of neuromarketing as well. Nanotechnologies are currently helping new diagnostic and therapeutic methods, as well as the use of drugs, regeneration of damaged nerves, neuroprotection, neuroimaging, and neurosurgery. For neuromarketing purposes, neuroimaging in conjunction with nanotechnologies is revolutionary for future research. Searching for new directions of application of nanotechnology will be necessary and key for future research. It is remarkable what nanotechnology is predicted to be able to do (Kumar, A., et al., 2017).

1.2 Neuromarketing

"Neuromarketing uses neuroscience to expose consumers' subconscious decision-making processes. Neuromarketers study brain and biometric responses as well as behavior to understand and shape how consumers feel, think, and act." (NMSBA, 2021).

It is not possible to observe exactly the interrelationships and influences in consumer behavior by traditional research methods. Neuromarketing originated naturally through development, research, and technological progress. Until then, it has not been possible to look into the human brain and observe the individual connections and functions that are related to shopping behavior and decision-making. Thus, a link has been established between the biological and social sciences, which lays a solid foundation for future neuromarketing processes and research. The basic research outputs of neuromarketing include finding out what product/service is desirable and popular. How the design of a given product influences consumer behavior and decision-making. Subsequently, we can observe the strength and importance of the brand and awareness of the brand, the way of internal (brain) and external reactions of respondents. With neuromarketing, we continue to track the impact of our ad campaigns, videos, and promotions themselves. We find out how the given promotions and marketing activities affect emotions and to what extent they are attractive, concise, and able to attract. The subject of research can also be deciding between several alternatives of advertising or campaigns, where we can use a sample of respondents to

obtain relevant data, which will then decide on the future success of the advertising campaign. Among other research options applied to consumer behavior, we advise observations and findings on the price of products and services through neuromarketing research. Price is one of the key success factors, especially when launching a product/service, but also during individual product phases and cycles. Therefore, one of the ways to find out the optimal price of products and services is to use neuromarketing research. If we can use neuromarketing research to identify at least one component of the marketing "four P's" we can talk about a big step forward in marketing research with the connection and application of research with real business. If consumers behave in the same way and have common and similar patterns of behavior, we dare to say that neuromarketing can recognize these patterns and then define the interrelationships and connections that can be applied in practice. However, many factors affect the quality and relevance of research results. One of them is the size of the research sample.

Neuromarketing is conditioned by the support of a specialist who examines and evaluates the information obtained from physiological and neurophysiological reactions. Jerry Zaltman of Harvard University first used the term neuromarketing in 2002. We use various methods to investigate reactions such as eye, face, skin reactions, or internal processes measured by electroencephalography (EEG is a basic diagnostic neurophysiological method based on sensing the electrical activity of the brain electrodes.), cognitive evocative potential (ERP measures the brain's response to a stimulus) and functional magnetic resonance imaging (fMRI) of brain activity. It should be noted that the mentioned research methods represent a revolutionary way of looking into neurological processes based on stimuli and the influence of the environment. Comprehensive results could not be achieved only based on inquiries, interviews, and surveys in the given issue (Shared, A.; Tanusree, D., 2015).

Neuromarketing can be used in marketing research to gain a deeper understanding of what consumers prefer, and what motivates them and can even help marketers gain insight into why consumers make choices. Today, neuromarketing is done through something called a Brain-Computer Interface (BCI). BCI is a communication path through which an external device receives information from the central nervous system. One of the most common BCIs used in marketing research is the EEG, which is connected to an external BCI system so that the neuro-marketer can see the output (Mridha, M.F., et al., 2021).

An EEG device measures electrical activity in the brain. When connected to an external BCI system, based on the EEG, it reveals patterns that can tell the neuro-marketer whether an individual is happy, sad, frustrated, distracted and many other emotions. In addition to EEG, many other physiological tools can be used in marketing research. For example, neuro-marketers have used functional magnetic resonance imaging (fMRI) to track activity in certain areas by measuring blood flow in the brain. Other neuro-marketers prefer less invasive measures such as eye tracking. This information helps neuro-marketers decide whether it's a good idea to run or change a

given ad. Why is neuromarketing research better than traditional marketing research? As psychologist Daniel Kahneman described, the human brain has two operating systems: System 1 and System 2. System 1 is automatic, effortless, and accounts for about 98% of our thinking. System 2, on the other hand, is conscious—it's deliberate, controlled, and only makes up about 2% of our thinking. When it comes to decision-making, Kahneman argues that System 1 almost always dominates over System 2, meaning that System 1 usually determines our behavior and decision-making (Kahneman, D. 2011).

1.3 Nano-neuromarketing

K. Eric Draxler says that nanotechnologies will evolve to a certain point where they will be able to build new physical structures in progressive stages - from nanometers, through micro-levels to macro-levels (Draxler, E. K., 1986).

Nanotechnologies are currently used in neuroscience to obtain neurophysiological signals. These signals are obtained to clarify the emotional states of individuals. Sophisticated algorithms are used here that can detect specific neurological and physiological patterns of behavior concerning different emotions. Opportunities for nano marketing research:

• the opportunity to use nano marketing technologies to measure emotional states in real-time
• use of small, portable nano-marketing devices
• measure neural and biophysiological signals using nano-marketing devices and technology
• combine laboratory experiments with everyday life tests involving nano-devices
• ensure the moral, social, and ethical requirements of nano marketing research
• balancing advanced nano marketing techniques with moral, social, and ethical requirements (Mileti, A. et al., 2016).

Modern nano-devices have functions that can record and measure the desired signals, all remotely. With the help of these modern devices, we can monitor the current state of heart rate, brain activity, respiratory rate, muscle activity as well as other external movements and conditions (Brown, L. et al., 2010).

The use of nano-devices in marketing research and the study of consumer behavior consists in measuring the brain activity of the respondent as well as other physiological conditions. The aim is to get relevant results and reveal emotional states that arise during shopping decisions or in everyday life. For example, the Electroencephalography (EEG) method, is very often used for such research (Balanou, E. et al., 2013).

One of the most accurate methods we can use in neuromarketing research is the fMRI method of imaging the respondent's brain activity. This is the most advanced research method, which on the other hand has its disadvantages. It is mainly the size of the equipment, the fact that the equipment must be placed in a special room (laboratory), is not portable and therefore the research must take place in an isolated environment that is not a natural environment for the customer, respondent, or research group. One of the main reasons for the use of nanotechnology in the field of neuromarketing is their properties as well as the possibility to use them anywhere and especially in the customer's natural environment. These devices can recognize several physiological and neurophysiological activities and signals of the respondent (Fernandes, M.S., et al., 2010).

Currently, brain activity can be modified and controlled using optogenetics - neurotechnology. We can explore the possibilities of neural activities and perform neural computations, which represents a huge advance in neuroscience. Optogenetic research has focused on neocortical, striatal, and hippocampal networks, revealing new possibilities for the neurophysiology of memory, executive processing, learning and perception. It is important to mention that optogenetic applications have shown enormous potential for revealing the behavior of human nervous systems as well as basic cognitive functions. Such findings help not only in medicine but also provide comprehensive knowledge for neuromarketing research. Optogenetic mapping of neural circuits can take neuromarketing to a new level (De Vittorio at al., 2014).

1.4 Ethical aspects of neuromarketing using nanotechnology

The basic standards and codes of ethics to be followed in nano marketing research using nanotechnology include:

• Voluntary consent of all research applicants
• Benefits from research outweigh risks (on the part of research subjects)
• Research should focus on the good of society and be of benefit to society
• The ability of research participants to withdraw/cancel participation, before or during the research
• It is necessary to avoid injury to candidates or any injury
• Researchers must have the necessary qualifications to carry out the research
• The human rights of researchers need to be respected
• Also pay attention to the mental health of research applicants and do not expose them to stressful situations (NMSBA, 2022).
• Medical research protects the life, health, privacy, and dignity of human research participants/subjects over the interests of society
• The necessary measures must be taken to protect the interests of human subjects from harm
• The importance of the objectives must outweigh the inherent risks and burdens on participants - no abuse, no harm to human health

• Research must be clearly formulated and submitted for approval with a clear ethical statement
• Respondents must volunteer and be informed of the implications of the research
• Scientists, research participants, and all other parties have ethical obligations that must be clearly defined.
• Compensation for participation damage and fairness for all involved (Bulley, C.A., et al. 2018).

Results and Discussion

From May to June 2022, we realized a survey of 77 respondents that focused on a general overview of nanotechnologies and their applications. The survey was realized in the google forms platform for creating surveys. Link: https://forms.gle/xxN5g5vCd6yiEBGj6 The survey was realized in the Slovak language for easy understanding and consisted of 4 main and two secondary questions about the age and gender of the respondents. As we mentioned, a survey was created for Slovak respondents, which means that the structure of questions and results was in the Slovak language. Below the graph, we can find explanations of the results.

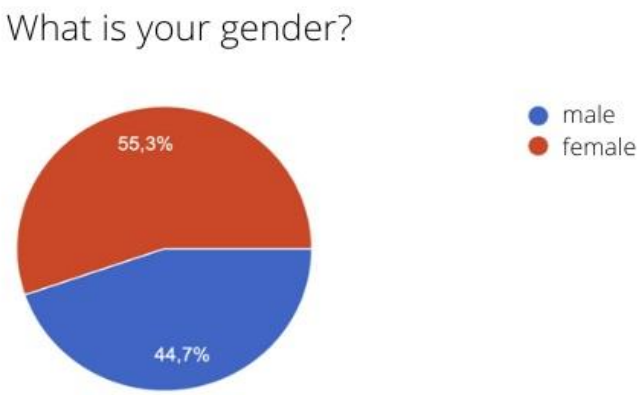

Figure 1: Percentage ratio between males and females participating in our research. Source: Own elaboration based.

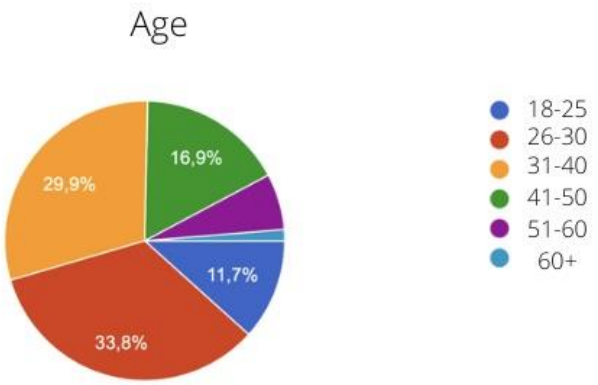

Figure 2: age structure of respondents. The group of respondents aged 26-30 years has the largest representation. The second largest group of respondents is between 31 and 40 years old. The group of respondents consists of a wide age range. Source: Own elaboration based.

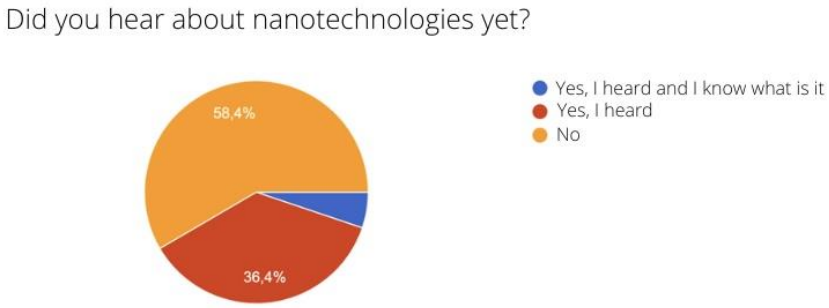

Figure 3: Did you hear about nanotechnologies? The majority of respondents, up to 58.4%, said they had never heard about nanotechnology. This percentage indicates weak awareness of the potential of nanotechnology. 36.4% of respondents said they had only heard of nanotechnologies. This means they could no longer explain how they work, what they are used for, and what they mean. Unfortunately, only 5.2% of respondents said they know what nanotechnologies are and understand their meaning and use. Source: Own elaboration based.

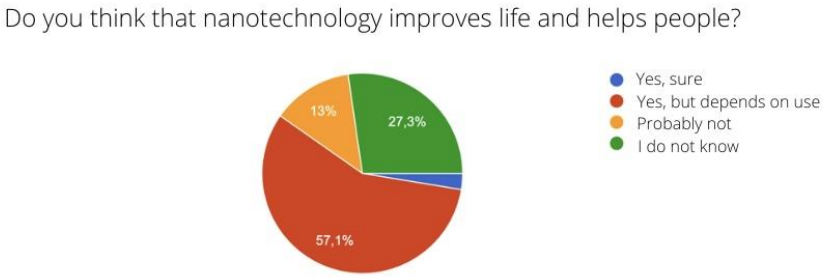

Figure 4: Do you think that nanotechnology improves life and helps people? Most respondents, 57.1%, said: it depends on their use. This means that nanotechnologies can be used for right and wrong purposes. 27.1% of respondents said they could not answer the question. 13% of respondents said they thought nanotechnology was not improving life around us. Only a skeptical 2.6% of respondents said they thought nanotechnology was improving life around you. Source: Own elaboration based.

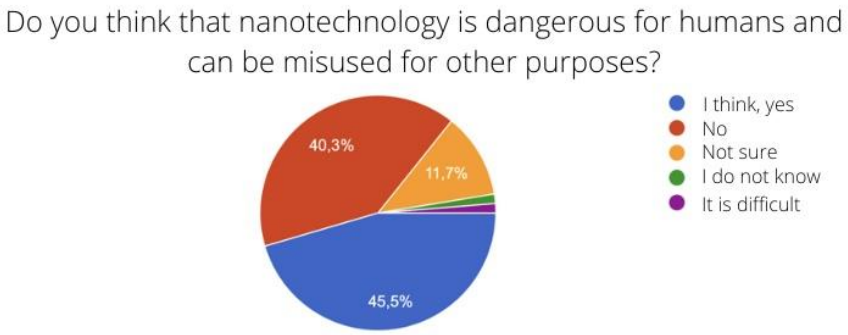

Figure 5: Do you think that nanotechnology is dangerous for humans and can be misused for other purposes? The largest share, with 45.5% of respondents said that nanotechnologies could be dangerous to humanity and could be misused for some bad ideas. On the other hand, 40.3% of respondents said they thought the opposite. More than 11,7% of respondents could not answer the question. Source: Own elaboration based.

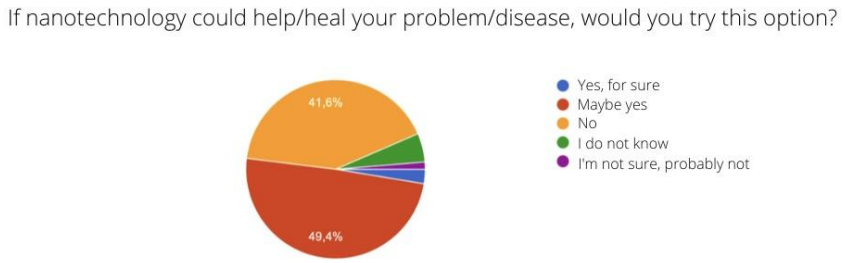

Figure 6: If nanotechnology could help/heal your problem/disease, would you try this option? The largest percentage of respondents, up to 49.4%, said they would try (doubt) this method of treatment or problem-solving. On the other hand, 41.6% of respondents would never try this method in the form of nanotechnology. The other respondents could not answer the question. Source: Own elaboration based.

2 Conclusion

Nanotechnology creates the division of the whole into small parts, using their potential and miniature size. We currently use nanoscience and nanotechnology in

many areas that improve life and solve problems. Whether it's microchips used in devices, life-saving medicine, or various scientific fields and research to help us understand problem areas. Such an area is also neuromarketing, which examines for example consumer behavior, shopping, and the whole process of decisions making in online and offline space. The combination of nanotechnology and neuromarketing creates a new area of possibilities that have not been possible before. We can use imaging devices allow us to show, for example, parts of the human brain and individual processes that take place deep into the brain. Indeed, some neuro-devices are not sufficiently capable of recognizing and recording brain activity deeply rooted in its structure. Simply put, they only examine the surface reactions and signals sent by the brain toward the surface of the cerebral cortex or skin. However, nanotechnologies allow much more. The possibility of importing small parts into human brain microchips that can work independently in the human body and obtain relevant data that they use only for neuromarketing research is unique. Nanochips in the human brain, for example, are also being developed by San Francisco-based Neuralink Co., founded by Elon Musk. The nano-chips that the company is developing are used for real-time communication between the brain and a computer, or communication between two independent chips implemented in the human brain. We can help solve neuroscience issues, reach data for marketing research and consumer behavior, and of course for medical purposes. The part of the paper also includes the online research created in the online form. For the paper, we set up a hypothesis that should clarify awareness of nanotechnology, and identify the main fears but on the other hand, identify the potential and breakpoint of rejection and acceptance of the nanotechnologies. The results and hypothesis of the research were partly surprising because most respondents did not know the concept of nanotechnology, respectively. she had no information about this topic. The results of the research, stand for that the awareness of nanotechnologies in Slovakia is still very weak. Credibility in nanotechnology is also part of it, with a large proportion of respondents stating that nanotechnology can be misused for purposes other than those designed. Nevertheless, a larger percentage of respondents would like to try nanotechnology and its solution in case of problems or diseases. The statement is that in the event of a positive increase in the chances of either treatment or problem-solving, people are willing to approach the application of nanotechnology and its use.

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