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Business Potential of Biohacking at Work

Studying the Degree to which Employees would Adopt Biohacking within their Working Context

Margaux Venet

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Pallot, Marc and Krawczyk, Piotr

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Abstract

In our modern economy, workers are overwhelmed by their high-demanding job; consequently, their well-being is suffering, and their performance is decreasing. No holistic approach has been developed to answer these issues; the ones existing target only one or few domains.

This paper studied the business potential of biohacking - recent movement that aims to optimize the body, mind, and environment - by researching the potential degree of people's adoption of this concept and its practices at work.

A holistic view of biohacking at work has been developed, laying the foundation for the adoption research framework of this study. The author tested the research framework by conducting a survey in which both quantitative and qualitative questions were asked. A mixed-method methodology has been used to collect relevant data.

The participants were globally positive about adopting biohacking practices at work. On the one side, respondents are curious to try, enthusiasts about being more efficient and productive in their tasks but also about increasing their well-being at work. On the other side, some people do not think all practices can be implemented at work. They do not feel ready yet due to a lack of familiarity with the concept, judged as not suitable for all.

Results have shown a correlation between the biohacking experience at work and the causal effect. It appears that the more satisfying the biohacking at work experience is, the higher the degree of people's adoption will be.

Future research could use a bigger and more representative sample to allow for inferential statistical analysis to test the validity and reliability of the biohacking at work adoption model.

Keywords/tags (subjects) biohacking practices, biohacking at work, employees, well-being, performance, adoption model, survey, mixed-method research

Miscellaneous (Confidential information)

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1 Introduction

1.1 Background, Motivation and Purpose

The author discovered randomly biohacking a year ago, while making online researches about healthy living and nutrition. While doing an internship at BRAINEFFECT - a performance food and supplements company - some months later, the author had the opportunity to deep dive into the biohacking movement since it is embedded in the firm culture. Employees implement biohacking practices to improve their well-being but also performance while the company arranged the workplace to support this process with for example ergonomic stand-desks or healthy lunch meals every Wednesday. By witnessing benefits to the whole firm, the author was interested after the internship to continue studying biohacking.

The Biohacking movement appears in the literature to be created in 2008, which may explain the low number of published empirical studies. Furthermore, most of them target the 'hard version' of biohacking referring to the cyborg and its human-machine concept. Some researchers have shown interest in biohacking within the workplace area but only by questioning the use of implants for employees. As a purpose, the author foresees much more potential in biohacking at work that would focus on a holistic approach seeking for employees' well-being and performance at work instead of focusing solely on implant devices.

1.2 Research Objectives, Questions and Approach

The healthy work environment that the author witnessed at BRAINEFFECT is far away to be common to all workplaces. In our modern economy, workers are overwhelmed by their high-demanding job; consequently, their well-being and health are suffering as well as their performance is decreasing. No holistic approach has been developed to answer these issues, the ones existing target only one or few domains. Therefore, the author has for objectives to draw a research framework that regroups the elements composing the biohacking strategy at work. The study also aims to evaluate the potential degree of adoption of this 'biohacking at work' approach in order to foresee if it has a business potential.

The main research question and sub-questions are the following:

1. What would be the degree of people's adoption and willingness to apply biohacking at work?

1.1 What are the topics linked to biohacking that can be implemented at work, in order to improve the overall well-being and performance of workers?

1.2 What are the perceived benefits and drawbacks of Biohacking?

1.3 What are the factors impacting employees' adoption of Biohacking at work?

To study the potential degree of adoption, the author has chosen to conduct a qualitative and quantitative empirical study through a survey questionnaire. It has been shared among BRAINEFFECT employees for collecting insights of both advantages and disadvantages of adopting biohacking at work and was extended to external individuals who currently work or had a work experience in offices previously. In this way, after introducing the concept of 'biohacking at work' through a mind map exposing the identified categories, the author would be able to evaluate the degree of respondents' willingness to adopt this concept and its practices.

1.3 Thesis Structure

The author begins to show that only a few studies have been conducted on biohacking and even less on the context of work. Since this movement is complex and has many senses, the author comes back to biohacking origins to explain the evolution and permutations of this movement. The aspirations of practitioners are exposed to understand the philosophy of biohacking where in the case of the biohacking at work model only its 'soft version' will be considered. After collecting the benefits and drawbacks of this version, the author presents a short overview of its business potential on the market. Then, since 'biohacking at work' refers to the workplace, the author tackles the current state of the art in terms of the workplace and its impacts on employees. Three identified strategies developed by experts to decrease these issues are considered. Besides, even if biohacking at work is not widely studied, the author reviews the previous work and gives examples of firms following some principles of it. Then, the review of adoption theories and models is

addressed. Finally, gaps in the current literature are identified and a research framework is proposed.

After this literature review, the next part presents the research approach and methodology chosen to conduct the survey. Then, the author presents the research results by analysing the collected data. Finally, the author unveils the drawn conclusions and finishes with a discussion of the limits of this study as well as its reliability and validity, and how this study has answered the research questions as well as presenting potential future research.

2 Literature Review

2.1 Existing Theories and Previous work

The chosen topic currently has a limited range of available publications. Indeed, several searches on Google Scholar, which were done with different terms, show the actual publication amounts by year. As shown on the first bar graph done bellow (Fig. 1), the term 'biohacking' has experienced an exponential increase in the number of publications each year since the movement was born in 2008. Apparently, there is a raise of interest concerning this topic, but it is still emerging; one may anticipate that the movement didn't reach yet its full potential. In other words, 469 published papers for 2019 is still insignificant compared to other topics such as 'biology' with an amount of 156 000 publications or even 'hacking' with an amount of 22 900 publications found for the same year.

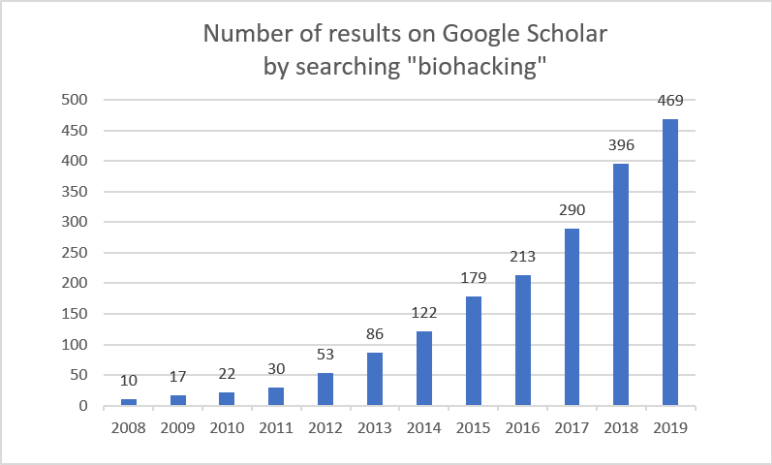

Figure 1. 'Biohacking' amount of publications found on Google Scholar (2008-2019)

Furthermore, after deep-diving into the topic of my thesis that combined 'biohacking' and 'work', the publication amounts found via Google Scholar were restricted to select the most relevant sources for preparing a state of the art. As shown in the second bar chart below, through the use of keywords matching with the thesis topics such as 'biohacking at work', 'biohacking factors', and 'biohacking effects'. The first one, is precisely what the author is determined to study as it can be understood with the sub-title of the thesis "Studying the degree of biohacking adoption in the context of work". The second and third keywords are strongly related to the identification of the key concept of biohacking. The keyword 'factors' means topics or categories of biohacking; the keyword 'effects' refers to the benefits and drawbacks of the Biohacking movement. Finally, this bar chart (Fig. 2) shows an increase of publications related to 'biohacking at work' that encourages the author to pursue a study.

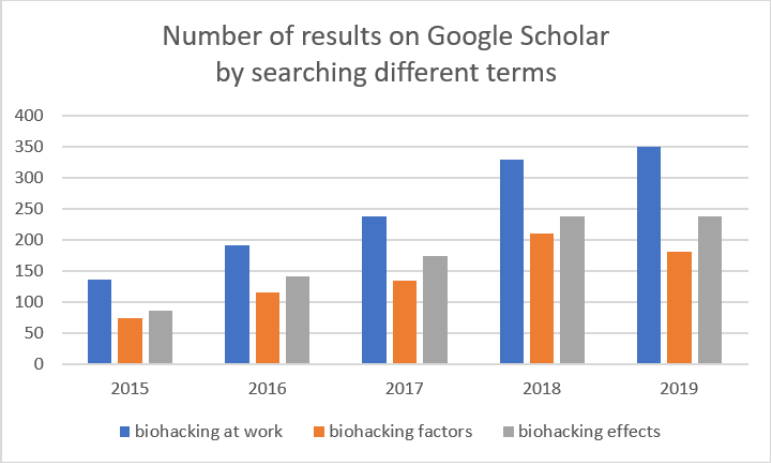

Figure 2. 'Biohacking at work', 'biohacking factors', and 'biohacking effects' amount of publication found on Google Scholar (2015-2019)

To support the claim of the author concerning the lack of information, some specialists referred it in their work. Firstly, some authors confirmed that biohacking or Do-it-yourself biology – we will see later in this paper, what encompasses biohacking - is a recent phenomenon (Landrain et al. 2013) and it started with the first association called DIYbio.org launched in 2008. Even nowadays, body hacking – another synonym of biohacking – Even nowadays, body hacking – another synonym of biohacking – is considered, according to Giger, and Gaspar (2019, 307), as a marginal practice limited to "*artistic exploration and citizen science DIY biology*

experimenters". Other scholars explained that the movement doesn't have any form of public outreach like advertising in order to be discovered by someone outside the system (Bihani et al. 2015); so, it makes it difficult to popularize biohacking in general. Secondly, the reason why there are few publications listed on Google Scholar is that the self-trackers – also part of the biohacking movement – didn't publish aggregated data concerning what they could experiment in the form of a peer-reviewed journal (Wexler 2017, 4). Giger, and Gaspar (2019) mentioned the low level of studies that have been done to reveal the main determinants and limits in the practice of body hacking. Finally, the results found by biohackers are still controversial. Indeed, biohacking is not recognized yet by health and medical professionals (Vennare, 2017) because there are not enough empirical/clinical studies to prove the efficiency of the discoveries (Munoz, 2019).

2.2 Biohacking

2.2.1 Origin of the movement

Biohacking origins go back a long way in history and are made up of many events but also other related movements that participated to its development. The author decided to synthesize all elements in a single table providing an overview of the chronologically classified milestones (Table 1). The author stopped at a strategic point when biohacking gain popularity outside the biohackers' community. Naturally, the movement is still evolving nowadays; however, the author will reveal how biohacking is evolving these last years in the next section.

Table 1. Biohacking Milestones

Milestone (Date)	Description	Source
Fermentation (Ancient Age)	Greeks and Romans used the fermentation process for producing e.g. alcohol.	Lorenzo, & Schmidt 2017
Biology science (XX century)	Biology science witnessed many changes due to better tools and models available to explore and exploit living systems.	Landrain et al. 2013
Synthetic Biology (1984)	It gathers biologists who create new biological entities or modify existing biological systems in their laboratories. It was	EBRC website; Gaspar et al. 2019

	practiced only in a conventional way by specialists in leading labs.	
Mention of 'Biohacking' (1988)	Apparition in *Playing god in your basement*, article published in the Washington Post journal. Just as hacking computers, people will follow the path of biotechnology and will be able to "*fiddling with the genetic code of a living organism*".	Schrage, 1988
Open source biology (2000)	Three synthetic biologists submitted a grant application to the US Defense Advanced Research Projects Agency for the creation of 'open source biology' to promote biology practices for all and easier access to equipment more affordable.	Meyer, & Wilbanks 2020
Genome Sequencing Technology (2003-2020)	The price dropped from $3.8 billion (with the Human Genome Project 1988-2003) to $1000 nowadays. Continuous innovation let specialists believe it could go down to $100 in the future.	Yahoo Finance, 2020
International Genetically Engineered Machine (iGEM) (2003)	People practice synthetic biology in domestic places (garages or kitchens) but also in public spaces. iGEM is an example of an independent and non-profit organization dedicated to the advancement of synthetic biology, education and competition, and the development of an open community and collaboration.	iGEM website
First Annual iGEM Jamboree (2004)	Designed for students, this competition regrouped 30 participants form North America. Now, each year 6 000 students from around the world present their work and compete.	Moo-Young, 2019
DIYbio.org (2008)	First association dedicated to do-it-yourself biology (DIYbio), created in Boston. The term DIY refers to an old American movement regrouping makers who work in their garages.	Delfanti, 2012
Biohacker spaces	Biotech enthusiasts gather together in biohacker spaces that are financed by university and government subsidies, crowdfunding or even membership fees (Fig. 3)	Sanchez, 2014
Biohacker spaces	Biohacker spaces gather scientists, software developers, hobbyists, designers and enthusiasts, that focus on various projects through workshops, guest lectures, member-led seminars, and hands-on activities.	Landrain et. al 2013
DIYbio Online Platform	Created to share DIYbio initiatives and learn about and from others; fostering opportunities and potentials where the DIYbio community can connect, meet, support, and work together.	DIYbio.org
Diversity of DIY biology community	Tim Gray, known as the UK's leading biohacker, explained how diverse the biohackers community is: "*Americans are generally more products- and supplements-focused with biohacking. The Scandinavians are more tech-based and into extreme nature like foraging. Here in the UK, we're more diverse and take the best techniques from all over the world*".	Sanghani, 2020
Example of DIYbio project: Amplino (2012)	Amplino is a portable and cheap device based on polymerase chain reactions (PCR) used for environmental, agricultural, veterinary, and medical diagnostics. It can be useful for instance to detect malaria in developing countries.	Landrain et. al 2013

Open Science (2010s)	As biology equipment became easier to manipulate, cheaper and not exclusive to specialists, practicing science and biology became a normal subject to study for high school or undergraduate students as well as amateur biologists.	Landrain et. al 2013
DIYbio gains traction (2015-2018)	DIYbio started to gain popularity outside the community of biohackers. The movement interests more and more media such as newspapers – The New York Times (Bromwich, 2018), The Guardian (Wall, 2015), BBC (Nye, 2018) – or mainstream scientific journals like Nature.	Alper, 2009; Ledford, 2010

Figure 3. Map locating 85 DIY laboratories around the world (found on the official website https://sphere.diybio.org/)

To sum up, from the fermentation process of the Greeks and Romans to genome editing by DIY biologists in biohacker spaces, biohacking has known a strong evolution through centuries. Some projects undertaken by biohackers - chip implanted under the skin -let emerge concerns and fear (1) that will be summarize in Table 2 below. Solutions have been found by the biohacker's community with some external help (2) in order to be accepted and able to contribute to scientific breakthroughs.

Table 2. Biohacking concerns and identified solutions

	Topic	Description	Source
1.	Comparison with Cyborgs	Cybernetic organism describes the association between human and machine. *"Grinders practice functional extreme body modification in an effort to improve the human condition.* [They] *hack* [them]*selves with electronic hardware to extend and improve human capacities*". Terms 'augmented human', 'transhumanism' or 'grinder' refer also to the same concept.	Clynes, & Kline 1969; Ramoglu, 2019; Biohack.me

	Comparison with Biopunks	This term comes from the movement cyberpunk in the 1980s and instead of dealing with computers, it focuses on "*biotechnology and hacking the gene pool*". Biopunk has a negative connotation due to the punk movement from the 1970s (symbol of rejection and political revolution).	Rolling Stones magazine, 2002; Schmeink, 2016
	Easy access to genetic engineering kits	People point out the dangerousness of the easy access of genetic engineering tools and kits that are not anymore reserved to official scientific or industrial laboratories as well as traditional academic.	Schmidt, 2008
	Accidents	Accidents may occur more often since the activity in garage labs is not regulated.	Delfanti, 2012
	No required skills	Biohackers are amateurs that don't require specific skills to experiment such as the whole basic practical knowledge obligatory in formal laboratories.	Tucker, 2011
	Biological weapons	Experiences on living organisms in garage labs can result in dangerous microbes that can be used as biological weapons.	Jewell, 2019; Hukku, & Saini 2019
	Bioterrorism	The notion of bioterrorism is used by the media and biohackers are compared to terrorists.	Delfanti, 2012; Meyer, 2016
2.	Monitoring	The Federal Bureau of Investigation (FBI) and the Presidential Commission on Bioethics keep an eye on biohacking because the identity of biohackers is diverse, unsure, and riskiness, as well as innovativeness levels of their experiences, are currently up to debate.	Delfanti, 2012
	Workshops to the biohacking community	The FBI sponsored since 2009 conferences in the form of outreach workshops to the biohacking community.	Sanchez, 2014
	Biosafety and biosecurity	This type of event brought great attention to biosafety and biosecurity issues.	Jefferson, 2013
	Code of ethics	Opportunity to elaborate drafts of a code of ethics like it has been done during the European and the North American congresses where all regional groups worldwide joined.	Landrain et al. 2013
	Positive environment	The biohacking community is willing to make efforts. Jason Bobe, co-founder of DIYbio.org claimed that DIYbio and iGEM want to develop a positive environment for biohackers with a code of ethics, norms for safety and shared resources for amateurs.	Kuiken, & Pauwels 2010
	Public biohacking lab	'La Paillasse' is an example of an official and public biohacking lab situated in Paris. It is insured and promotes documented adherence to safety regulations.	Landrain et al. 2013

	Q&A platform	It gives the opportunity to amateurs to ask questions to members of the Association for Biosafety and Biosecurity (ABSA Int.) and professional biosafety experts can answer.	Landrain et al. 2013; DIYbio.org

Between the fear of 'human-machine' with cyborgs, rebellion with biopunks but also accidents in garage labs, biological weapons, and so on, the biohacking community had to find ideas to reassure sceptics of their aims and peaceful intentions. Therefore, biohackers created a code of ethics, work in public open spaces for the majority, and have access to online platforms to ask questions or discuss biosafety and biosecurity.

Finally, the biohacking movement is on the right track to gain trust and has a positive future ahead. Indeed, the US National Strategy for Countering Biothreats stated that biohacking in garage labs plays a role for the future physical and economical security of the USA: "*From cutting-edge academic institutes, to […] private laboratories in basements and garages, progress is increasingly driven by innovation and open access to the insights and materials needed to advance individual initiatives*" (National Security Council 2009, 1). Some experts would like to see also a change of mindset from the society by allowing biohackers to progress in their work while following their discoveries in order to have a higher chance to get promising outcomes (Jewell, 2019).

2.2.2 Between technology and biology: the aspirations of a biohacker

The 21rst century is the perfect era for the emancipation of biohackers since technology is in symbiosis with biology as Steve Jobs claimed: "*the biggest innovations of the 21st century will be at the intersection of biology and technology*". Nowadays, some emerging technologies focus on processes that enhance the biological function of the organism (Gaspar et al. 2019). These activities are described as any "*modification aimed at improving individual human performance and brought about by science-based or technology-based interventions in the human body*" (Coenen et al. 2009). Biohacking is thus the ideal mix between both entities as

Delfanti described the movement: "*direct translation of free software and hacking practices into the realm of cells, genes and labs*" (Delfanti 2010, 108).

However, an etymology analysis of the work 'biohacking' is crucial to understand later the goals of a biohacker. Biohacking is a combination of two words: 'bio' and 'hacking'. Although 'bio' referring to 'biology' is easy to identify, 'hacking' is a bit more complex due to its evolution of meaning through time. Initially, the term hacking was coined by MIT students in the 1950s to describe the action to adjust electrical systems in an uncommon manner (Stein, 2018). Levy (1984) identified the activities of these individuals working with the technology which helped afterwards to democratize this word and incorporate it into our common dialect. For a time, hacking was connoted negatively when it referred to illegal activities performed by computer programmers who wanted to have access to protected or locked informatic systems (Stein, 2018). Nonetheless, a time came when Zuckerberg (2012) restored the image of this term by describing 'hacking' as a way of "*building something quickly or testing the boundaries of what can be done*" but also "*get*[ting] *things done better and faster*". Hackers have unlimited possibilities to work on systems since they are part of our modern world. Indeed, Buchheit, lead developer of Gmail, supports this idea by saying "*wherever there are systems, there is the potential for hacking, and there are systems everywhere. Our entire reality is systems of systems, all the way down*". He also thinks "*those with this mindset are the ones who 'transform the world' across industry, governance, and even religion*". (Reagle 2019, 7.)

Consequently, it was normal that biohacking emerged from the hacking tendency (Stein, 2018) as they have a lot in common. They both enjoy understanding and modifying a system (Kelty, 2010) but they request overall to have the right to access, make, and modify things (Delgado 2013, 2). Whereas hackers work with technical hardware and software, biohackers concentrate their attention on biological hardware and software, respectively bodies and minds (Thomas, 2004). Finally, biohackers also use the Internet to diffuse information. Indeed, DIYbio forum discussions have been created like Reddit.com where biohackers can interact, share knowledge, experience, and advice. (Wexler, 2017,3.) Online platforms are also a way for DIY biologists to join and collaborate on projects (Benkler, 2006).

Even if everyone is free to practice biohacking which means a multitude of different profiles exist, there are still some common characteristics and distinctive goals that can be regrouped in the table below.

Table 3. Common characteristics among biohackers

Goals	Ideas	Description	Source
Large range of values		DIYbio practitioners embody various values such as "*rebellion, hedonism, passion, communitarian spirit, individualism, entrepreneurial drive and distrust for bureaucracies*".	Delfanti, 2013
Renew of sciences and biology	Review	They want to review how science has been conducted until now.	Delgado and Callén, 2016
	Create new forms of life	Biohackers intend to understand, reshape, and create new forms of life.	Lorenzo and Schmidt, 2017
	Different from institutional scientists	A "*renewed enthusiasm for exploration and discovery*" is what makes the difference between an institutional scientist and an amateur biologist.	Delgado, 2013
	Maker culture	Biohacking belongs to the "maker culture" which *"places a high value on tinkering, engineering, and creating things from* scratch".	Delgado, 2013; Dunbar-Hester, 2014; Newitz, 2001; Wexler, 2017
Redistribution of power	Decentralization policy	Biohackers aim to redistribute power and initiate a decentralization policy.	Delgado and Callén, 2016; Donovan, 2019
	Emancipate closed systems	Technologies that work as strategies for "*emancipating closed systems of knowledge and production*".	Donovan, 2019
	Extend existing boundaries	Biohackers attempt to broaden the circle by resituating the territories of institutionalized and corporatized production and drawing new boundaries.	Meyer, 2013; Ratto, 2014
Medical knowledge and equipment for all	Symbol of democratisation	DIY amateurs advocate the freedom to access medical knowledge, technology, and participation.	Donovan, 2019
	Domesticate biotechnology	"[Biohackers*] are domesticating biotechnology*".	Cowell, 2013
	Example of project: EpiPencil	After the price of an epinephrine autoinjector (EpiPen) reached $318 in 2016, the biohacking group "The Four	Brown, 2017

		Thieves Vinegar Collective" released on the net instructions to explain how to build a legal DIY version for about $30.	

Finally, biohackers aspire to three goals: renew of sciences and biology, redistribution of the power, medical knowledge, and equipment for all. Besides, it is difficult to define the DIYbio movement because there is a variety of descriptions (Seyfried et al. 2014) and permutations have been invented (Meyer, 2016). In other words, the sub-categories of biohacking have been created to approach the movement differently. Munoz (2019) tried to regroup all types into three categories. The first one is the 'hardest' version with grinders and cyborgs, described previously. The second one regroups DIY biologists practicing in their garage labs or biohacker spaces. The third one is a 'softer' and 'more accessible' version (Elkrief, 2019) that pops-up recently and will be at the centre of the study conducted by the author.

2.2.3 A softer version of biohacking

We saw previously with Stein (2018) how the term 'hacking' evolved over time. Its alteration happened when O'Brien, a writer and digital activist, coined the term 'life hack' in 2004 while he was giving a speech at O'Reilly Emerging Technology Conference in California (Reagle 2019, 3). It describes originally how "*computer programmers were creating shortcuts to make their lives easier*" but soon, with the excitement of social media, everybody starts to share their hacks: parent hacks, cooking hacks, happiness hacks, and so on (Stein, 2018). Hence, a hack in our modern society corresponds to "*a strategy or technique for managing one's time or activities more efficiently*" according to Google Definition. Behind 'life hack' hides the notion of lifestyle design (Reagle 2019, 3) that is to say making changes and pursuing a systematic approach (ibid., 4) in order to improve the daily life and to "*become the best version of yourself*" (Laffin, 2017).

All hacks have given fall into two categories: physical and mental capacities. The first one includes all interventions that affect the body and its functions (Ahteensuu 2016, 20) like the immune or digestive systems that can be optimized through nutrition. The well-known motto 'You are what you eat' deeply rooted in the society beliefs: everything that we introduce into our bodies alters our behaviour. Munoz (2019)

introduced the notion of 'nutrigenomics' to define the last subculture belonging to biohacking. It is directly related to nutrition because it approaches "*the study of nutritionally manipulating the activity of your body*". The second category regroups all medical hacks (Elkrief, 2019) that affect the mind and its functions. There are technics to improve well-being such as meditation (Ahteensuu 2016, 20) but also chemical enhancement products to improve cognitive functions (Gaspar, & Giger 2019) like in the movie 'Limitless' where the main character takes smart drugs to become a genius (Laffin, 2017).

Overall, life hacking - an example of self-help - pursues two objectives. On the one hand, people are attracted by this recent phenomenon because they want to "*hack their health*" (Elkrief, 2019). In fact, as the 'practical philosophy' suggests, individuals focus on what is worthwhile in life - here their health and well-being - and try to find a way to realize it - biohacking (used interchangeably with life hacking) is here the solution found to apply it (Reagle 2019, 6). However, it didn't have been always the case and the relationship between humans and health evolved through the centuries. Whereas they thought for a while that health was predestined and dictated by the god(s), they started to trust and rely on medical professionals when the healthcare system has been invented (Walls et al. 2019, 1). Anderson (2018) decrypted this system which is still used within our modern societies. He noticed a problem in the functioning of this system, not by meaning it is broken but more outdated compared to the current population needs. Indeed, our traditional health care system is characterized as a sick-care structure because it relies on a pathogenesis model through which professionals focus on the origin of the development of a disease and treat it consequently. He quoted his mentor Dr. Appelgate to highlight how the medical ideology works: "*Much of health care is organized and delivered to mend the broke, treat the ill, and cure the sick. Not to help us stay healthy*". This is how Antonovsky, a professor in medical sociology, coined a new model called 'salutogenesis' that will find a balance with the other one. This model has for purpose to figure out the factors that encourage health and well-being at first. (ibid., 2018) Whereas in the traditional sick-care system decisions belonged to experts leaving patients disempowered and passive (Walls et al. 2019), everyone has now the choice to be proactive, responsible, and to self-manage their health

thanks to this salutogenesis model that led to a self-care approach (Anderson, 2018). Some other factors strengthened this emergence such as access to medical information online, changes in medical education but also homeopathic and natural remedies (Walls et al. 2019). Dr. Zhavoronkov, CEO of Insilico Medicine and author of *The Ageless Generation: How Advances in Biomedicine Will Transform the Global Economy*, reminds that two groups of people can be identified within developed nations: "*society is currently split into two extremes. There's the highly health- and performance-conscious and the very health-ignorant. The first group is pushing themselves to the new limits and the other is driving the obesity epidemic*" (Sanghani, 2020). It means not everybody is concerned or interested in their health, but the author will focus on the first group of people described by Dr. Zhavoronkov. Biohacking is thus a way to democratize health science because citizens have access freely, and they can decide to apply hacks to take advantage of it (Gaspar et al. 2019). Moreover, biohacks are valued because traditional medicine doesn't cover topics that biohacking does such as mental health, woman health, or chronic disease (Elkrief, 2019).

On the other hand, biohacking focuses on a second goal: performance. Whether it is a sportsman who wants to improve his results in a competition or a businessman who wishes to be effective in his work, performance is concerning most of the people living in a capitalist society. Indeed, profit motive and competition are among the main characteristics of capitalism. Reagle (2019) explained that the core values of life hacking - a synonym of biohacking - are 'American individualism', 'pragmatism', 'entrepreneurial mindset', and 'endless ability to overcome obstacles' (6.), fitting perfectly to the second objective of biohacking. Capitalist societies make people always looking for better and more, rarely satisfied with what they have. That is why biohacking gets its inspiration from tech entrepreneurs of Silicon Valley. Dave Asprey is the best example for representing the tech entrepreneur who popularised biohacking. He spent 20 years of his life and $1 million to hack his own body and claims to have lost 100 pounds (45kg) and increased his IQ by 20 points thanks to biohacking. (Sanghani, 2020) He founded two companies - Bulletproof 360, Inc. in 2013 and Bulletproof Nutrition Inc. in 2017 -, has written five books and coined the 'Bulletproof Coffee'. It is a brewed coffee mixed with grass-fed unsalted butter and

medium-chain triglyceride (MCT) coconut oil that is consumed the morning in order to provide fast energy to the brain and boost fat-burning process in the organism (Steen, 2017). On the Bulletproof website, it is said that Bulletproof coffee is a high-performance food, used to optimize mental and physical performance. Moreover, biohacking generates a lot of enthusiasm and curiosity so many writers, podcasters, and practitioners start to share tips and methods about performance and productivity. For instance, Merlin Mann wrote *43 Folders*, named for the technic of classifying upcoming tasks in folders, Gina Trapani launched her website *Lifehacker.com* which has gain popularity among the biohacking community, and Tim Ferriss - a famous practitioner of lifestyle design - has a famous podcast called *The 4-Hour Life* that deals with hacks to simplify and automate daily life (Reagle, 2019; Pash, & Trapani 2011). Finally, biohacking was the source of many public events worldwide like the Health Optimisation Summit in the UK or the Biohacker Summit originated from Finland regrouping thousands of biohacking amateurs that have access to conferences and workshops.

Therefore, optimizing health and performance are the two main goals that motivate biohacking amateurs to invest in themselves thanks to life-hacking. They apply hacks but they need to understand how changes impact their organism. A movement has been developed in parallel to biohacking to answer to this problematic: Quantified Self (QS). Founded in 2007 by Wolf and Kelly, two editors of Wired magazine, QS defines collecting data with emerging technologies to gain valuable insights about daily experiences and activities (Lee, 2013). Self-trackers individuals follow a self-experimentation policy because they test their hypotheses, collect data, and try to make sense of it (Wexler 2017, 4). Data is considered as a light that illuminates knowledge of the self (ibid., 3) and empowerment (Sharon, 2017). David Asprey even said: "*We're now capturing more data on what it means to be a human being than at any time in history […] and what we're learning isn't just telling us what we are. It's telling us what we can be*" (Vennare, 2017). This community is growing as fast as biohacking and it has spread internationally. According to Nafus, and Jamie Sherman (2014, 1787), the QS community counted round about 20 000 amateurs in 2014 with more than 100 groups spread in 30 countries.

To sum up, the author introduced the topic of a softer version of biohacking that has been democratized in order to adapt to people's interests in health, well-being, and performance. This behaviour reflects a healthy lifestyle that more and more individuals are following nowadays, and life-hacking helps them to reach it. The author will now share all the categories in which biohacking can act in daily life followed by the advantages and disadvantages that may result from implementing some biohacks.

2.2.4 Benefits and drawbacks of implementing biohacking

Biohacking covers a wide range of topics and practitioners can choose to target a specific domain depending on their needs for improvement but also the ones they want to discover. On his blog, Dave Asprey shared a *Beginner's Guide to Biohacking*, useful to identify everything that biohacking includes. Figure 4 below is a mind map showing twelve sub-categories such as Environment, Nutrition, Sleep, or Oxygen, and each of them goes in detail by suggesting some methods and experts in these topics.

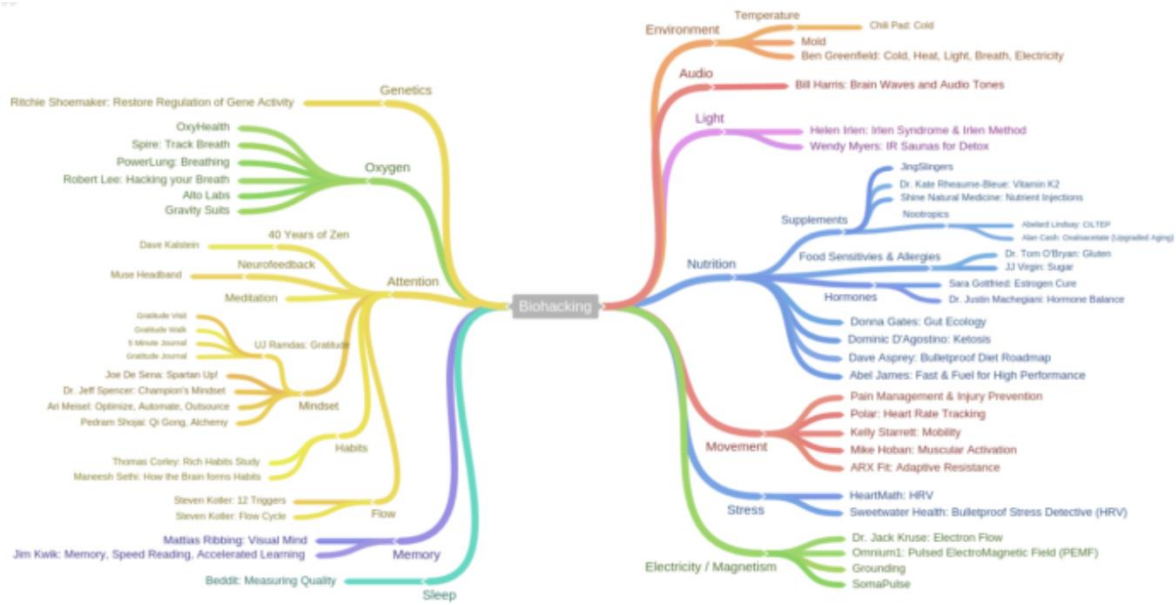

Figure 4. Mind map found on the blog of Dave Asprey
https://blog.daveasprey.com/beginners-guide-to-biohacking-101/

For instance, the sub-category Memory is split into two ideas. The first one is to implement the Visual Mind technic, strongly related to mind mapping. A mind map is beneficial for the memory because this visual thinking tool helps to structure information for the purpose of being able to analyse, synthesize and recall the given

topic afterwards but also to generate new ideas. The second idea is to try the Speed Reading and Accelerated Learning technics to support the brain to remember information of a text following certain methods. Two names are written on the mind map of Dave Asprey: Mattias Ribbing and Jim Kwik. He suggested these persons because they are masters in the art of training memory.

Studying the benefits and drawbacks of biohacking is a huge work if it goes in detail in each sub-category like the positive and negative results from electrical stimulation. The goal here is to discuss in general the implementation of biohacking according to the process of self-experimentation (Table 4). Practitioners can witness various consequences that can be beneficial (+) or not (-) for them.

Table 4. Benefits and drawbacks of self-experimentation

+/-	Idea	Description	Source
+	Change of behaviours	Self-experimentation helps biohackers to change systematically their behaviours for the purpose of analysing the outcomes.	Walls et al. 2019
	Outside of the comfort zone	They go out from their comfort zone and habitual routines to discover solutions to problematic behaviours.	Neuringer, 1981
	Active participant	Active participants because they acquire knowledge by relying on themselves during the research process.	Walls et al. 2019
	Control health	They are seen as individuals that learn how to better control their health (e.g. number of calories needed).	Lupton, 2016
	Long-term benefits	They can study long-term benefits because they think constantly about ways to improve health.	Robert, 2004
	Holistic approach	They project themselves and think about the big picture (e.g. by maintaining a record of data, they can build hypotheses to modify their current application and provide positive implications for future behaviours).	Munoz, 2019; Dallery et al. 2013; Walls et al. 2011
	Own experience shared online	Online platforms where the e-community can discuss methods, learn from each other, and find support for personal decisions like a change of lifestyle.	Walls et al. 2019; Carah et al. 2016
	Ripple effect	One experiment creates in general a ripple effect of subsequent discoveries that lead to unexpected results.	Robert, 2004
	Contribution to scientific exploration	Even if biohackers don't follow a strict scientific protocol, they make experiences under much more realistic conditions.	Robert, 2004

-	Unclear limits	Difficulties to draw the boundaries of self-experimentation to see how far is too far.	Dyck, & Stewart 2016
	Push limits of the body	They often push their body to an unknown limit which can result in obsessive behaviours to always want more and do better but also unsafe manners of doing and harmful repercussions.	Munoz, 2019; Hukku, & Saini 2019
	Question of ethics	Grinders assume that the human body is a machine and will react the same, but the organism is a living entity and has biochemical reactions completely different from a robot.	Ruckenstein, & Pantzar 2016
	Lack of consequences understanding	Informed consent is fundamental while practicing self-experimentation and the person doesn't always realize all possible consequences before starting a study.	Dyck, & Stewart 2016
	Biased approach	Guided by their interests and motives, they can bias certain results which is problematic for mainstream sciences to valid findings.	Dyck, & Stewart 2016
	Not a substitute of sciences	Self-experiments cannot be considered as a substitute of sciences or gives any diagnosis and prescription	Vennare, 2017

To sum up, we saw that biohacking covers many different fields whether in nutrition or magnetism. Most of the benefits and drawbacks of self-experimentation have been tackled so we will now pursue with the business potential that emerges from this DIY movement.

2.2.5 Business potential of biohacking

As the author explained in a previous part, one of the aspirations of biohackers among others is to represent a symbol of democratisation: the freedom to access knowledge, technology, and participation. They are also driven by the idea of sharing their discoveries to make progress in the sciences and health industries, without expecting a financial profit (Jorgensen, 2012). Indeed, according to Alessandro (2012), they just aspire to open new markets where "*smart, small-scale, open source models could compete with Big Bio*[1]". However, more and more biohackers seize the

[1] Big Bio regroups "pharmaceutical corporations and federally funded university laboratories" retrieved from http://artsci.ucla.edu/events/outlaw-biology-public-participation-age-big-bio

entrepreneur mindset and participate to the capitalist system in which most of the populations are living.

As biohacking regroups various topics, a multitude of products and services can be monetized. Table 5 below regroups examples of companies that make business within several categories: gene editing, self-tracker devices, medical analysis, supplements, sports or meditation.

Table 5. Businesses around biohacking

Category	Firm	Description	Source
Genes editing	ODIN	Commercialization of kits to carry out genetic experiments at home between $20 and $2000.	ODIN website
	23&Me	First DNA kit (2006) at $99 allowing clients to discover their origins, ancestries, and more about their DNA.	23&Me website
	Ginkgo Bioworks	Bacteria production for industrial applications ($150 million value in 2017).	Lorenzo, & Schmidt 2017
Wearable self-trackers	Fitbit	Sports bracelet	Fitbit website
	Polar	Heart rate sensor	Polar website
	Apple watch	Smart watch	Apple website
	Oura Ring	Smart ring that tracks sleep and activity	Oura ring website
Personal Medical analysis	Biodata	Full medical check-up for 150 000 roubles ($3000) mainly to executives and businessmen.	Malpas, 2020
	Cerascreen	Specific tests (e.g. Omega 3 or vitamin D) done by the customer at home. He will get his results online and personal advice.	Cerascreen website
Supplements	BRAIN EFFECT	Supplements and products for mental and physical performance.	BRAINEFFECT website
	HVMN	Nootropics that improve cognitive functions.	HVMN website
Physical exercises	UNLTD	Biohacking Recovery Wellness Centre as a "*healing space where individuals can go to revitalize, rejuvenate, and recharge*".	Salonga, 2020
Meditation	Headspace	With 11 million downloads, the firm has more than 400 thousand paying subscribers and $50 million annual revenue.	Reagle, 2019; Forbes journal, 2017
Environment	Pili	From the 'Grow your Ink' project developed in a biohacking lab to the creation of a start-up in 2015. Pitch to investors and products potentially launched.	Meyer, & Wilbanks 2020

To bring explanations to certain categories, self-trackers facilitate the analysis of many elements: "*physical movement, food and drink intake, energy expended, sleep levels, blood glucose levels, cholesterol levels, calories burned, mood and emotion, inactivity*" (Williamson 2015, 137). Consumers are fans of these new gadgets. Studies demonstrated that 15 % of Americans wear daily this device and 56 % wish to manage their health behaviour thanks to it (Sanders, 2017). It leads to a phenomenon called mHealth, described by the World Health Organization in 2011: "*medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices*" (cited by Rich, & Mia 2017, 85). Besides, meditation or yoga are kings on the well-being market, estimated to be worth a billion-plus dollars (Reagle 2019, 137).

The biohacking industry is expected to have a global compound annual growth rate of 19,42 % between 2017 and 2023 and could reach a value of £19.7 billion (Sanghani, 2020). Biohacking answers a problem that will concern all of us in the near future. According to a report of Michel Servoz - Special adviser to European Commission's president Juncker - Artificial Intelligence (AI), robotics and automation are going to shape our societies, impacting the work organisation, education systems, governments, and so on. The AI report puts forward hypotheses that technologies will be at the core of the organisation and business of firms so workers, to avoid being displaced, should learn new skills (Servoz 2019, 67), participate in training (66.) but also acquire digital competences (60.). Biohacking has always been interlinked with technology, cyborgs huge fans of the human-machine concept. For instance, a prosthetic hippocampus - in the form of a microchip - is a project that aims to recreate the human memory process (Hogle 2005, 708) and could help persons suffering from memory loss. More generally, this type of brain-electronic devices highly interests the military that reserves 10 % of the Defense Advanced Research Projects Agency budget for the Brain-Machine Interface Program (Hoag, 2003).

Moreover, as the AI report suggests, new job sectors but also new jobs will emanate (Servoz 2019, 47) from the Fourth Industrial Revolution (Schwab, 2016). For example, Servoz (2019, 47) thinks data scientists, "*part mathematician, part computer scientist and part trend-spotter*" will be involved. They will be "*responsible for collecting,*

analysing and interpreting large amounts of data" (ibid., 47) for the purpose of helping firms to improve their operations and gain a competitive advantage over their competitors. This type of profession echoes the quantified-self movement in correlation with biohacking. Dr. Hukku and Dr. Saini (2019) suggested also that biohacking will create job opportunities. The instance, a human body designer will aim to create organs from a patient's own cells in order to reduce immune rejection (ibid., 2019). Once again, it reflects the gene editing interest from biohackers.

In a nutshell, biohacking has a lot to offer to the market. Many companies and start-ups seize the opportunity to launch their brand, products, and services around biohacking. The business potential of DIY biology is going further by looking to the future. Soon AI, robotics, and automation will be part of our personal and professional life and biohacking will be here to develop technologies to enhance human functions, analyse huge amounts of data but also find solutions for sustainability.

2.3 Workplace

2.3.1 Workplace issues

2.3.1.1 Change in work dynamics

We saw previously that Artificial Intelligence, robotics, and automation will transform our current workplace and its organisation, but this change has already begun with the digitalisation and will only expand and deepen (OECD, 2017). Nowadays, most of our daily economic, organizational and social activities are penetrated and impacted by digital devices, and online practices (Larsson, 2016). Our capacity to store, process, and communicate is radically changed (Macías, 2018). The spread of Internet generated a global 'information space' (Boes, & Kämpf 2007) where torrents of data are exploding (Rutkowski, & Saunders 2010) and are available unlimited times and in unlimited places.

On the one hand, it impacts certain firm structure and operations. In fact, new platform-based business models emerged in diverse product and service markets (Briken et al. 2017, 1). From transnational companies like Amazon, Facebook, and Google, to niche-related businesses, all of them are not working like 'traditional'

enterprises (Lazonick, 2009). On the other hand, the 'information space' impacts the workplace in a way that the time and work location no longer matter. According to Kirsh (2000), office work is not procedural and straightforward anymore. Indeed, this author testified that modern workspaces now include virtual spaces where "*desktops and applications have their own worlds of organizational structure, information space, and workflow requirements*". (20.) First, the 'organizational structure' that Kirsch mentioned corresponds to new modes of work (e.g. cloud and crowd working) and a new global division of labour (Briken et al. 2017, 62). Second, the 'information space' refers to new forms of communication and cooperation (e.g. professional online discussions with Slack or group projects with Asana). (ibid., 62.) Third, 'workflow requirements' became difficult to follow and high-demanding for employees.

First of all, the workflow changes the way employees do their job. This workflow is multifaceted: "*it takes place in many environments, involves many tools, and requires considerable mental effort*" (Kirsh 2000, 34). Therefore, a recent phenomenon was born, media multi-tasking (MMT), where workers switch from one task to another, one device to another - desktop screen, laptop, tablet, and phone - and various environments - virtual vs. real world - interfere (Leary, 2018). It even went outside of the work area to become the modern way of life of people in which they deal with personal situations and elements in the same manner (Kirsh, 2000). Moreover, the workflow has intensified, and workers are witnessing an increase in working hours because technology-based jobs mean that employees should be available at all times and in all places (Degryse 2016, 44) thanks to, smartphones, WIFI, free videoconferences and cloud-based document sharing (Valsamis et al. 2015, 25). Besides, frontiers between professional and personal life are blurred because of new technologies that irrupt un both environments (Degryse, 2016). On the one side, employees bring work at home by checking professional emails, replying to them, and even receiving information or calls about work during the weekend. According to the American Psychological Association (2013), half of all workers use daily work-related communication outside of work because they believe it can be beneficial for them. On the other side, during working hours, employees get distracted by their private life: consulting private emails, notifications from social media, texting SMS,

and so on (ibid., 2016). Finally, the management of employees has changed. A 'management euphoria' resulted from the digitalisation with managers expecting to gain better control and transparency over their employees (Briken et al. 2017, 63). Taking the example of a driver, the geolocation system lets the manager know exactly when the employee starts the truck, which route is being taken, and at which time the freight has been delivered or arrived at the premises (Degryse, 2016).

Digitalisation reshapes the work organisation in a way that a lot of responsibilities and expectations from workers are delegated. The 'do better, go further' mindset resulting from capitalism is even more possible thanks to high-speed networks, Big Data, and new forms of electronic devices (ibid., 7). However, the global economy is experiencing a decrease in productivity "*from an average annual rate of 2.9 percent between 2000-2007 to 2.3 percent between 2010-2017*" (The Conference Board Inc., 2019). Many reasons are addressed such as macroeconomic causes but at the microeconomic level, within the workplace, workers are also responsible. Indeed, slowed productivity is due to several psychological and physical sufferings among workers who can't cope with their environment anymore.

2.3.1.2 Impacts on workers

The most common symptom developed by working persons is stress. Indeed, according to the American Psychological Association (2016), 33 % of them feel chronically stressed because of work. Smith (1994), described stress as a stage when the organism can't adjust to additional internal or external stimuli also called 'stressors' (Dua, 1994). In fact, modern work requires stress-inducing demands (Burton et al., 2012) during long working hours (Leary, 2018) extended outside the workplace up to the home (Mettling, 2016). Therefore, two types of stress have been identified: 'overwork stress' because of long hours of work (Pencavel, 2015) and 'anticipatory stress' due to working outside work hours (Belkin et al. 2016). The individual doesn't have any longer the ability to find a balance (Kets de Vries, 1979) and it can lead to undesirable consequences (Makhbul et al. 2013, 125). First, the health and safety of the person concerned are in danger because stress lowers illness resistance, sleep quality, and the decrease of concentration rises risks of injuries and accidents (ibid., 125). Besides, relationships with colleagues or managers as well as personal relationships are usually altered (Kirsh, 2000). A recent phenomenon

emerged from digital workspace with a virtualisation of human relations: the 'Fear of Missing Out' or FOMO. This occupational disease is a "*form of social anxiety leading to an obsessional relationship with professional communication tools*" (Degryse 2016, 44). Moreover, the World Health Organization claimed that stressed workers are likely to "*smoke more, exercise less and have an unhealthy diet*" (WHO, 2017). Millions of dollars are spent in medical support for these individuals in need to decrease their level of stress (Stein, 2018).

Furthermore, the author mentioned previously that multitasking is the new way of working and dealing with elements. Although one would have thought that multitasking increases employees' efficiency, it has been found out that it doesn't improve work, decision-making, or productivity (Byyny, 2016). The Journal of Experimental Psychology: Human Perception and Performance (Vol. 27, No. 4) concluded that it was particularly true for complicated or unfamiliar tasks because it takes mental extra time every time the individual shift from one task to another (Smith, 2001). On the contrary, multitasking brings a lot of disadvantages to workers. To name a few, multitasking is associated with distractibility (Moisala et al. 2016). According to a survey conducted by McKinsey Global Institute in 2012, employees sacrifice 2,6 hours daily on average to read and answer emails which corresponds to 28 % of their working day (Sunshine, 2012). We can imagine that it is not done in a row but several times during the day and even simultaneously with other tasks. Besides, multitasking is a waste of time that generates a lower attention span which corresponds to a state of inaction (Byyny, 2016). In general, multitaskers witness a decrease of their cognitive performance (Ophir et al. 2009; Moisala et al. 2016).

Multitasking is also related to information overload (Byyny, 2016). Indeed, increasing demands in cognitive tasks (Jaeggi et al. 2007) and given the complexity of them lead to difficulties to deal with office activities effectively and cope with information (Kirsh 2000, 20). The upshot is a more complex work environment saturated with multitasking, interruption, and information overload (ibid., 20) that burns time, attention, and brainpower (Byyny, 2016). Byyny explained in his article *Information and cognitive overload* (2016), human capabilities have a limit and it is not because there is a continuous growth in information and technologies that neurons in the brain are more numerous or the memory increase in capacity. (3.) The brain didn't

adapt yet or maybe never will, so this mismatch leads to cognitive overload. The journalist defines this term as a stage when "*the volume of information supply exceeds the information processing capacity of the individua*l". (8.) There are plenty of negative consequences within the external environment such as miscommunication with colleagues, altered personal relationships but also within the internal one with a loss of job satisfaction (Kirsh, 2000) until being transformed in burnout (Bynny, 2016).

The term 'burnout' appeared for the first time in the 1970s in a medical report of the American psychologist Freudenberger. He described symptoms of "*physical or mental collapse caused by overwork or stress*" (Staff Burn-out, 1974). The idea of potential symptoms floated for a while before that burnout has been officially recognized in 2019 by the WHO as an 'occupational phenomenon' (Oehler, 2019). Indeed, the 11th Revision of the International Classification of Diseases (ICD-11) qualified burnout as a phenomenon that can only occur in the workspace so it can't be applied to other areas of life (WHO, 2019). Burnout can manifest itself in different ways among individuals (Türk et al. 2020) but it embraces in general two dimensions. The first one regroups reactions on the body: progressive energy depletion (WHO, 2019), fatigue, headaches and sleep deprivation (Türk et al. 2020). The second one is directly linked to the mind: emotional exhaustion (Maslach et al. 1997), psychological pressure (Leary 2018, 45), and loss of enthusiasm (Bakker et al. 2014, 390). Rutkowski and Saunders (2010) introduced a new type of burnout born from current digital societies: emotional and cognitive overload (ECO) with information technology. They defined it as "*negative manifestations resulting from proposed or actual digital technology usage and the corresponding cognitive and emotional failures to resolve the high mental load with information delivered by technology*". (96.) Besides, burnout has several repercussions at work: reduced professional efficacy (Maslach et al. 1997; WHO, 2019), disengagement or reduction in the willingness to perform (Leary, 2018; Stein, 2018), isolation and distance from others (WHO, 2019), voluntary intention to quit (Bedeian et al. 1991). According to Gallup's 2017 State of the Global Workforce Report, 87 % of employees in the world are either not engaged or actively disengaged at work (Stein, 2018).

In addition, due to digitally transformed workplaces, tensions emerged between employees and employers around power, autonomy, and control (Fleming, & Sturdy 2009). Indeed, the author mentioned previously a digital management possible thanks to the rise of new technologies. Concerns and questions arise about this topic among employees. They fear to witness an increase in pressure or oppression feeling, a risk of being under observation or 'policed' about what they do and how they act that can lead to a form of penalties and loss of trust (Degryse 2016, 39-40).

To sum up, digitalisation and new technologies reshape the work organisation: the emergence of virtual spaces, multiplication of platforms and communication tools, blurred frontiers between professional and private life, the explosion of data, multitasking, and longer working hours. All these changes altered the well-being, health, and behaviour of workers. They have higher levels of stress, get distracted more easily, suffer from cognitive overload, emotional pressures but also burnout. All these negative consequences can be lowered or disappear with the adoption of specific strategies: workplace design ergonomics, cognitive enhancement, and productivity technics.

2.3.2 Strategies focusing on employees' well-being and/or performance

2.3.2.1 Ergonomic workplace design

The working environment is constantly overloaded, and an inadequate workplace infrastructure is one of the causes (Kirsh 2000, 22). Kirsh (2000) defined a working environment as a space that "*constrains both what it is possible or acceptable to do, and what happens as a result of performing actions*". Initially, the working environment is not really supportive with workers for facilitating movements and information management, minimizing interruption and disruptiveness. (36.) There is a need to design an operational environment (30.) and to do so, a trend that began in the industrial workplace (Zha, 2003) and now is spreading to office workplace, arose: ergonomic workplace design (also called 'Ergonomics').

Derived from the Greek words *ergo* (work) and *nomos* (natural laws), ergonomics means the 'natural laws applied to work' or more simply 'laws of work' (Mat et al. 2017). Therefore, ergonomics is a broad science with a multitude of working conditions that can impact the comfort and health of workers (Kolgiri et al. 2016).

Fernandez and Goodman (1995, 229) laid the foundation of this science: "*The goal of ergonomics is to fit the task to the individual not the individual to the task*". This notion endures and is reflected in its objective of implementing a "*safe and productive workplace to the worker's comfort to fulfil the goals and objectives of the organization*" (Kolgiri et al. 2016). Indeed, the ergonomic process engages all parties - employees, management and administrators - in order to change the organization at the micro and macro ergonomics levels which will generate a return on investment for the company thanks to higher employee work health satisfaction, higher productivity and cost savings (ibid., 2016). Designing the workstation with an ergonomics approach, involves four main variables: human, machine systems, job design, and work environment (Makhbul et al. 2013). It considers the human's physical, psychological, and biomechanical capabilities (Fernandez, & Goodman 1995). Figure 5 below gives an overview and summary of ergonomics workstation factors and stress outcomes mentioned.

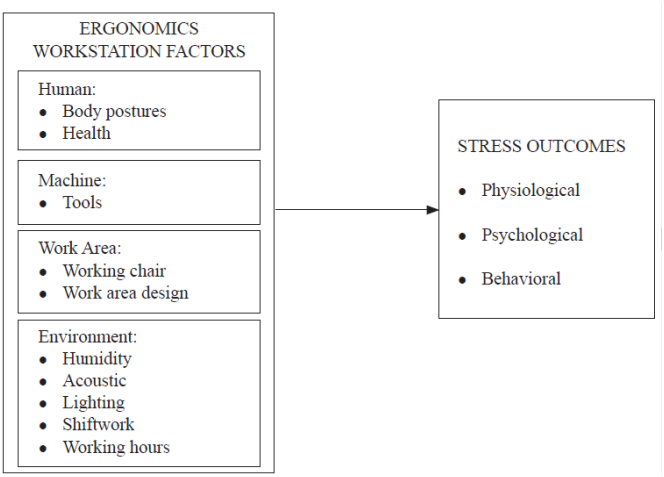

Figure 5. Research Model of the ergonomic workplace design (Ergonomics and Stress at the Workplace: Engineering Contributions to Social Sciences, 2013).

Ergonomists will, therefore, participate in the "*design and evaluation of tasks, jobs ,and products in industries*" (Kolgiri et al. 2016). On the one hand, they will focus on the ergonomics workstation factors. The first two - human and machine - aim for erasing all potential overload muscles by promoting dynamic work, showing correct natural postures, and adapting work surface height, but also training workers to use proper equipment (Fernandez, & Goodman 1995). Then, the third factor - work area - is described as 'physical layout' by Kirsh (2000) and it is one of the solutions to

reduce cognitive overload. In fact, the physical layout brings closer physical and cognitive opportunities to agents at the right place and time in order to lead them to "*notice possibilities they might otherwise overlook*". (51.) For example, while thinking about the work area design, relocating employees in the room depending on their complementary knowledge may create positive outcomes such as common help and support. (52.) Finally, the fourth factor - environment - regroups three elements belonging to the physical infrastructure: humidity, acoustic, lighting systems but also visual (related to visual ergonomics). Shift work and working hours will not be analysed by the author due to their inaccuracy with the study. Humidity or temperature levels are essential in the workspace and impact the work performance. On the one side, extreme heat can generate mental depression (Clark, 2002) but on the other side, extreme cold can alter mental capacities that may lower performance and higher absenteeism (Smith et al. 2000). Moreover, a good acoustic within the working room is fundamental even if it is an open space. Noises come from various sources: telephone ringing, keyboard typing, loud conversations, piped-in background music, loud furniture, and so on. Reducing noise levels will decrease work stress (Fairbrother, & Warn 2003) and distractibility. Light is also helping to reduce work stress (Sutton, & Rafaeli 1987). Indeed, high levels of glare and minimum lighting can cause eye strain (Aaras et al. 2001). Finally, visual ergonomics is crucial since computer work is a stressful task visually, not offering a distance viewing which is for most relaxed posture (Anshel, 2007). Individuals are also working longer in terms of years; their eyes are aging as well as a decreasing ability to focus; adjustments must be adopted (ibid., 420).

On the other hand, ergonomists must include stress outcomes impacting the workers psychologically, physiologically, and behaviourally. The author will not separate the results by categories but the benefits and drawbacks in case of a good or bad ergonomic workplace design. On the one side, the most common impact due to inaccurate ergonomics within the workplace is musculoskeletal disorders (MSDs), which include low back pain (Fasanya, & Shofoluwe 2019). It refers to "*injuries and disorders of the soft tissues […] and nervous system. They can affect nearly all tissues, including the nerves and tendon sheaths, and most frequently involve the arms and back*" (Kolgiri et al. 2016). Then, WHO (2017) listed the other most common

occupational diseases on their website - chronic respiratory diseases, noise-induced hearing loss, and skin problems - but they have a higher chance to emerge in industrial workplaces than offices. In office workplaces, a firm that would fail to implement ergonomics principles, would have higher a chance to observe emotional depression and physical exhaustion among employees but also waning productivity and product quality among its organization (Shikdar, & Sawaqed 2003; Shahraki, & Nooh 2011). On the other side, an operational environment designed with an ergonomics approach will improve the cognitive and physical workflow (Kirsh 2000, 41) by removing barriers to quality, productivity, and human performance (Kolgiri et al. 2016). Indeed, it has been proved that ergonomic improvement increases productivity (Fernandez, & Goodman 1995; Das et al. 1996; Safety & Security Services, 2004; Battini et al. 2011). Furthermore, workers will feel less stressed (Tarcan et al. 2004; Jamieson, & Graves 1998) and tired (Kolgiri et al. 2016), will have global improved health and safety (Safety & Security Services, 2004), will have access to better information management (Kirsh 2000, 36) as well as a simplification and efficiency of work thanks to a higher quality environment (Fernandez, & Goodman 1995).

To sum up, ergonomic workplace design is a first solution to answer workers nowadays feeling overwhelmed by their workspace as well as more and more challenging work organization. Once parameters of the work environment have been tackled, a complementary solution can be considered: the cognitive enhancement.

2.3.2.2 Cognitive enhancement strategies

Societies in developed nations are growing in a ‘knowledge economy’ where creativity and talents participate in the creation of economic opportunities (Yigitcanlar et al. 2007). Knowledge workers or the creative class are therefore key elements in this perspective (Florida, 2005; Baum et al. 2006), characterized as ‘engines of growth’ (Glaeser, 2000; Raspe, & van Oort 2006). Knowledge became a source of added value in the economy (Stehr, 2017). According to Collins (1993) there are five types of knowledge: embrained, embodied, encultured, embedded, and encoded. Embrained knowledge depends on conceptual competences and cognitive abilities (Blackler 1995, 1023). Indeed, cognitive abilities concern cognitive

tasks defined as "*any task in which correct or appropriate processing of mental information is critical to successful performance*" (Carroll 1993, 10). Supporting the brain and its cognitive functions is thus crucial to participate to the knowledge economy.

Cognitive enhancement is the method to improve the cognitive functions of the brain. It is defined as "*the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems*" (Bostrom, & Sandberg 2009, 1). Cognitive enhancement embraces a broad spectrum, from medical to psychological interventions but also the amelioration of external technological and institutional structures supporting cognition (ibid., 3). Dresler et al. (2019) reinforce this idea by qualifying cognitive enhancement as a 'multifaceted concept'. As shown in Figure 6 below, improving brain function involves numerous interventions, not only with one cognitive enhancer. The authors created a chart representing three areas of intervention: biochemical, physical, and behavioural.

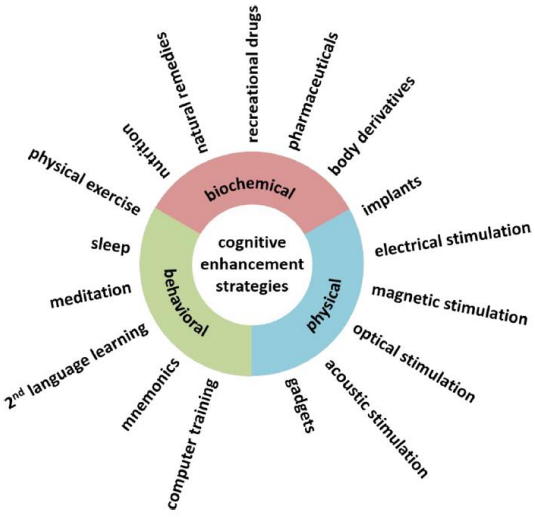

Figure 6. Cognitive enhancement interventions different in their mode of actions. Retrieved from *Hacking the Brain: Dimensions of Cognitive Enhancement.*

This graph has a lot in common with the mind map of Dave Asprey because it contains most of the sub-categories highlighted by the Bulletproof expert such as 'acoustic stimulation' that would correspond to 'audio'. However, the repartition differs as this graph focuses on a specific entity: the brain.

The author decided to regroup enhancement strategies divided by three categories - biochemical (1), behavioural (2) and physical (3) - in Table 6 below to understand which concepts within each category might be adopted by workers to improve their cognitive efficiency for accomplishing working tasks. The author will not tackle all 17 concepts but the ones that are the most relevant and have a greater amount of empirical studies.

Table 6. Cognitive enhancement strategies and implementation at work

Cat.	Strategy	Description	Source
1	**Nutrition**	Balanced nutrition with enough nutrients participates to well-being and avoid chronic inflammatory, anxiety, and depression.	Sovijärvi et al. 2019; Foster, & McVey Neufeld 2013
	Recreational drugs & pharmaceuticals	The topic is debated since they can be judged as 'invasive' in a narrow medical sense.	Dresler et al. 2019
		They are part of 'nootropics' or 'smart drugs' because they have been found to improve memory, mood, and increase alertness.	Lannu et al. 2008
		They are better than cognitive enhancers because they have a neuroprotective capacity.	Giurgea et al. 1983
		Most of the nootropics' types can be purchased without a prescription so some experts are worried about the long-term health effects and some users witnessed side effects like headaches or insomnia.	Kendall, 2016
	Nootropics for workers	Employees can consume nootropics to "*get the job done*" and produce "*higher-order cognitive work*" since they are "*judged by the work* [they] *produce*".	Murray, 2017; Interview with Nootrobox, 2017
		They should be careful to not be addicted to these products and not relying only on their performance.	Dresler et al. 2019
2	**Physical activities**	Health benefits such as lowered risk of illnesses and cancers or decreased depression and stress.	HHS, 2008
		Improvement of brain functions by increasing the amount of gray matter - component of the nervous system - specifically in areas essential for the memory.	Erickson et al. 2014
		People exercising rarely or a bit have a bigger decline in processing speed and episodic memory compared to people exercising often or very regularly.	*Northern Manhattan Study* cited by Willey et al. 2016
		Our society has been diagnosed sedentary and employees are directly exposed due to office work.	Owen et al. 2010

	Team sports within the organization	Sedentary workers perform worse in cognitive tasks compared to active people.	Ratey, & Loehr 2011
		Social dimension: practicing sport in a group increases team spirit and communication between participants.	Cohen et al. 2010
		Drawbacks: employees could feel forced to participate (abuse of power) or feel in competition, therefore afraid to be excluded from the group if low results.	Calderwood et al. 2016
	Meditation	Meditation refers to many techniques (contemplation, concentration, use of nature sounds, meditative movement or breathing exercises, etc.) that work at different levels: senses, mind, intellect, and emotions.	Sharma, 2015
		Meditation is "*the practical application of psychology to the area of human wellbeing and performance*".	Taft, 2015
	Meditating during breaks in a workday	Some psychological benefits: lower stress levels, reduced anxiety and depression, improved memory, and cognitive function.	Goyal et al. 2014; Manocha et al. 2011; Van Dugt, & Jha 2011; Dillbeck et al. 1986
		Some physiological benefits: reduced chronic pain, reduced oxidative stress in the body, slowing down the aging process of the brain.	Zeidan et al. 2011; Schneider et al. 1998; Gard et al. 2014
	Sleep	Disrupted sleep has many contributing factors "*from environmental and lifestyle factors to psychosocial issues and iatrogenic effects*".	Medic et al. 2017
		Sleep is essential to most physiologic processes such as brain functions.	Watson et al., 2015
		Sleep disruption leads to short- and long-term health consequences: cognitive, memory, and performance deficits, increased stress responsivity, somatic pain, emotional distress, and mood disorders.	Medic et al. 2017
	Sleep and productivity	According to the study, workers sleeping less than 6 hours per day report to be 2.4% less productive than workers sleeping between 7-9 hours.	Hafner et al. 2017
	Power naps at work	Naps are beneficial for the memory and can erase performance deteriorating effects caused by sensory overload.	Mednick et al. 2002

3	**Brain stimulations**	Non-invasive methods: transcranial direct current stimulation (tDCS), transcranial random noise stimulation (tRNS), transcranial magnetic stimulation (TMS).	Coffman et al. 2014; Snowball et al. 2013; Luber, & Lisanby 2014
		For instance, TMS increases the excitability of the motor cortex that leads to better performance in procedural learning tasks.	Bostrom, & Sandberg 2009
		Possible side effects: scalp burns (from tDCS) or seizures (from TMS) but also "*potential build-up effects across multiple sessions or in sensitive nontarget areas*".	Dresler et al., 2019; Shirota et al. 2014
	Devices available at work?	Brain stimulations are not yet well accepted socially because they may generate higher negative effects than cognitive training exercises.	Dresler et al., 2019
		It is not sure that TMS will ever be "*a practical useful enhancement method*".	Bostrom and Sandberg, 2009

In the table above, the author tackled the main points presented in Figure 6 that regroups cognitive enhancement interventions, different in their mode of actions. Overall, body derivatives, computer training, and second language learning didn't have been mentioned because the author judged them irrelevant as part of the world of work. Moreover, the topics of gadgets and implants are according to the author more related to biohacking that will be tackled in the last section. Finally, mnemonics - set of techniques created to artificially enhance memory (Bellezza, 1981) - are part of a vast array of mental techniques that seek of bringing effectiveness and focus (Byyny, 2010). This family of methods will be discussed in the following section because, after devoting an entire analysis of cognitive enhancement strategies, another category that helps to reduce the current work organization's impacts on workers, should be introduced.

2.3.2.3 Efficiency enhancement methods

Efficiency is at the centre of the economy where companies aim to produce goods and services (Leibenstein 1966, 392). According to Schmidt and his colleagues, productive efficiency refers to "*the ability to avoid waste by producing as much output as input usage allows, or by using as little input as output production allows*" (Fired et al. 1993, 9). Transposed into the context of employees at work, they can

appropriate the concept of efficiency to accomplish their tasks successfully by avoiding wasting time, efforts, and energy (Cambridge Dictionary). Drucker (1967) defined the recipe for accomplishing tasks efficiently: the focus of attention and devotion of the time.

On the one hand, there is the law of concentration that says individuals can focus only on one thing for about 10-25 minutes. In the flow zone, "*this time may be several times that, even hours*" (Sovijärvi et al. 2019, 396). Being in the flow state is the representation of being efficient. Its creator Csíkszentmihályi (1990) defines 'flow' as "*the mental state of being in harmony with the information processed by the consciousness as well as one's own goals*". At this moment, the worker will experience a time of peak emotion and performance, where everything else around is shut outside consciousness. Therefore, the notion of "*doing things that make* [him/her] *meaningful*" but also push him/her to his/her competences' limits, is crucial to reach the flow state (Sovijärvi et al. 2019, 407). The flow model below shows that the flow state is situated at the edge of a high challenge level and a high skill level.

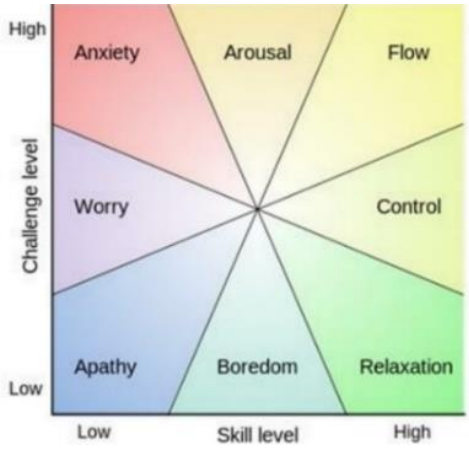

Figure 7. Csíkszentmihályi 's Flow Model (1990)

On the other hand, a worker who wishes to accomplish efficiently a task needs to devote smartly his/her time to it. For that, the person will adopt a time management strategy. It includes setting short and long-term goals, defining priorities, planning, and organizing activities but also reducing activities as well as external factors that waste time (Byyny, 2010). First of all, the Objectives and Key Results (OKR) strategy coined by Grove in 1983, is a goal-setting methodology driven by outcomes instead

of tasks (Chau, 2018). In general, main OKRs are created upstream a time period (month, semester, trimester) by the manager or team leader and are updated at the end of the time frame. Starting from this framework, employees can set their own OKRs and adopt the SMART approach (specific, measurable, assignable, relevant, and time delimited) to define doable actions.

Secondly, it is necessary to classify tasks by order of priority because "*efficiency without priorities is a near enemy of effectiveness*" (Reagle, 2019). It is during a speech in 1954 that the former US President Eisenhower said: "*I have two kinds of problems, the urgent and the important. The urgent are not important, and the important are never urgent*" (cited by Oppong, 2017). Afterward, he incorporated this principle into his time management method called the Eisenhower matrix. Besides, Covey (1989) repackaged this matrix into his own time management grid that classifies information and responsibilities into four quadrants: urgent, non-urgent, important, not important (Byyny, 2010).

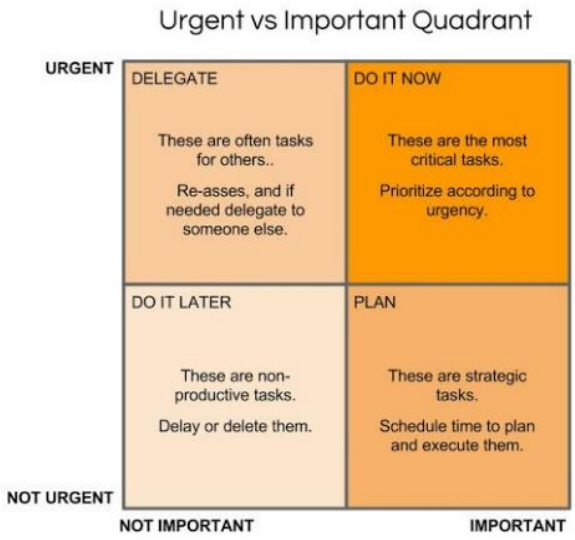

Figure 8. Covey's time management matrix (1989). Retrieved from "Hacking Life: Systematized Living and Its Discontents"

Covey (1989) explained: "*The key is not to prioritize what's on your schedule, but to schedule your priorities*". Indeed, a study published in the J*ournal of Consumer Research* (2018) discovered a phenomenon that the researchers called 'The Mere Urgency Effect' which demonstrates that people are more likely to prioritize tasks with a deadline over tasks less urgent even if they offer a greater reward at the end (Zhu et al. 2018).

Once the worker set priorities, he/she can implement the 1-3-5 rule introduced by Cavoulacos and Minshew (2017). It consists of establishing a list of tasks that need to be done and then choose "*one big thing, three medium things, and five small things*" to do on a given day (ibid., 2017). Then, within the day, it is possible to adopt the Personal Kanban method to evaluate the progress of the tasks by placing them in three columns: To Do, In Progress, Done (Benson, & De Maria Barry 2011).

Furthermore, the employee has a time limit to realise daily tasks and it is the number of working hours that make the delimitation. According to the law of concentration, it is humanly impossible to be focused for the whole working day but only by phases. Therefore, some work rhythms methods have been invented to split the day by work in which the individual will be fully concentrated on the task, not disturbed by external factors, and will be able to reach the flow state. For instance, the Pomodoro technique consists of setting an alarm to work 25 minutes, then taking a five-minute break, and starting again until completing four work sessions. At the end of these sessions, the worker takes a longer break maximum of 30 minutes and can do another Pomodoro block (Cummings, 2020). However, if this technique is not fitting to the person's tastes, the Flowtime method has a different approach. It is about splitting a project into smaller parts and let free the worker decides how long to work on the task, until he/she needs a break. Then, a break will be taken, and the number of minutes will have to be reasonable and appropriate to the working time slot (Saladino, 2017). Taking breaks between working sessions is fundamental to keep a certain high-energy level and mental agility (Sovijärvi et al. 2019, 394).

Ultimately, efficiency applied at the individual level is a good start, but it should be extended to the firm level. In other words, more structure and organization will benefit everyone, and some techniques or tools can be used in order to be more efficient. Kirsh (2000) gave some ideas such as coordinating activities at the group level, wall charts, or whiteboards for conducting meetings (49). but it is also preparing meetings in advance in order to have a short and efficient session by setting objectives, a time limit, what is expected from each individual and their roles.

To sum up, the author explored three solutions that aim to diminish the impacts of the economy overload over employees: ergonomics workplace, cognitive, and

efficiency enhancement approaches. Overall, these methods have more or less a common goal: the well-being of employees.

2.3.3 The pursuit of employees' well-being

Employees' health and well-being are key elements to generate performance within a company that will outperform competitors that don't adopt health and wellness programs. Indeed, according to Grossmeier and his colleagues, firms that received high scores on the HERO Employee Management Best Practices Scorecard, has a higher stock performance appreciation (235 % on average) over a six-year period, compared to other companies from the S&P Index (159 %) (Grossmeier et al. 2016). Other kinds of health and well-being programs exist as well as awards to promote the hard work and efforts of companies that take care of their employees. For instance, the REBA Employee Wellbeing Awards are given during an annual ceremony to companies that engaged itself the most to improve staff well-being. For the 2020 edition, Volkswagen Financial Services won the award of the 'Most effective development to a wellbeing strategy' with 92 % of employees who feel healthy and fit doing their job (REBA website).

2.4 Biohacking at work

Biohacking at work is not a subject broadly studied empirically (1540 results on Google Scholar since 2008, date of the creation of the biohacking movement). The main topic discussed and related to biohacking is about wearable sensors and implants which are highly debated in the work area. Elon Musk once said: "*if humans want to continue to add value to the economy, they must augment their capabilities through a merger of biological intelligence and machine intelligence*." (cited on Michael Page, Bio-hacking: going "beyond human"). He refers to the 'beyond human' concept that imagines the future world of work with technology enhancing workers' ability to perform and realise their tasks easier, faster, and with better outcomes (ibid., Bio-hacking: going "beyond human"). The cyborg and Quantified-Self aspects from Biohacking resurface apparently in the debate towards microchip and smart implants but also wearable devices. It is not anymore a question of management control with electronic panopticon technologies (Bain, & Taylor 2000) but the

employees' acceptance to operate a change in their life that will benefit the company, reaches a superior level.

On the one hand, the softer implementation is to wear sensors at work for different purposes. First of all, it has been adapted to the work environment for tracking employees' well-being. The HR team will be therefore more capable of managing employees' health and safety issues related to tiredness, strains or pains (Becker, & Smidt 2016; Schall et al. 2018) and then being able to offer solutions. For instance, the healthcare insurance group Aetna has been encouraging its employees to sleep enough during the night by rewarding them financially (Belvedere, 2016). Indeed, the Aetna chairman and CEO Mark Bertolini believes in the sleep virtues and explained the concept of his wellness program "If they can prove they get 20 nights of sleep for seven hours or more in a row, we will give them $25 a night, up to $500 a year" (Interview with CNBC, 2016). However, many concerns and questions emerge such as security and privacy of data (Renault, 2020), compliance, distraction or material quality/costs (Schall et al. 2018) that create a barrier to adoption, not considering the difficulty for the HR department to analyse employees' data (Angrave et al. 2016).

On the other hand, the most difficult implementation for employees to accept is implantable technologies. The use of microchip hit first technophiles and facilitates the daily life of more than 3 000 Swedes nowadays since Sweden was the first country to adopt this gadget in 2015 (Bas-Wohlert, 2018). Then, the use of this technology extended to the workplace with firms suggesting the idea to its employees. For example, at Three Square Market, more than 80 workers volunteered to have a chip injected into one hand. Now on, they can open security entrances, purchase products at the cafeteria, log on their computers (Metz, 2018). Some chips also contain basic medical information of the user that could be useful in case of urgent health problems requiring a fast intervention (ibid., 2018). The goal is to make the employee working life easier and materializing medical information into the implant could be a way to take care of the employee's health. Based on three companies from different countries, a study conducted by Gauttier (2019) analysed arguments (Figure 9 below) against and in favour of the implant for employees.

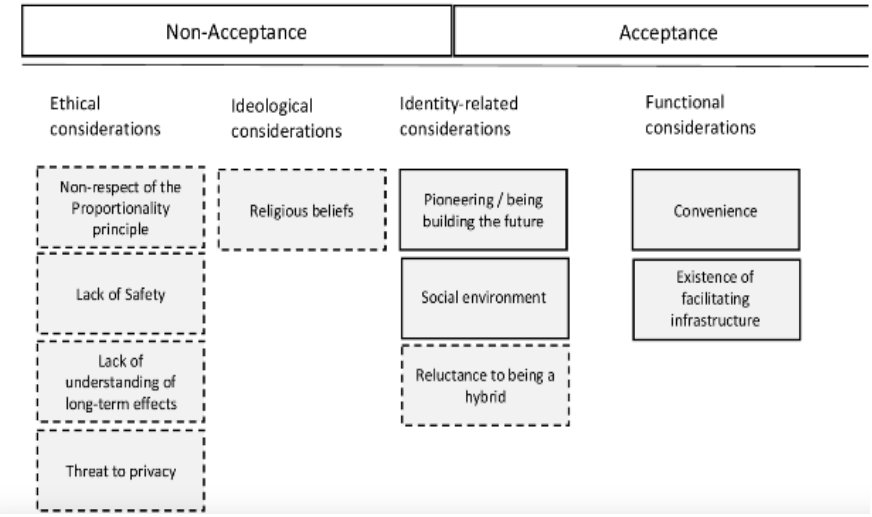

Figure 9. Initial modelling of drivers of acceptance or resistance to insideable technology (Gauttier, 2019).

Whereas opinions are divided, the non-acceptance part seems to occupy a big part: the threat of privacy, lack of understanding long-term effects, reluctance being a hybrid, etc. Overall, this could mean that employees are not yet ready for having an implant.

Furthermore, there is another subject that discussed biohacking. Few studies and most articles are interested in companies implementing some life-hacks, another aspect of the biohacking movement, within the organization. These firms seek for creating an optimum environment for their employees by following - consciously or not - some basics life-hacks. On the one side, there are large firms like Facebook and Google that were (not anymore on the top 10 of the 'best places to work') (Wagner, 2019) famous for offering one of the best working environments to their employees with alternative workspace designs, recreation during work hours, free health food but also mindfulness training (Leary, 2018). On the other side, more specialised companies in biohacking due to what they are selling, follow also some biohacks. For example, the 6-year company HVMN standing from 'Health Via Modern Nutrition' and previously called 'Nootrobox', manufactures and sells nootropic supplements as well as products for the ketogenic diet (HVMN website). According to Kendall (2016), employees at HBMN practice 36 hours of fasting during their week at the office and feel "*super productive*" the day they don't eat. Some of them consume also supplements such as vitamins as well as nootropics.

Finally, Reagle (2019) associates life-hackers with the creative class that describes "*the rise of creativity as a fundamental economic force, and the rise of a new social class*" (Florida, 2012). The rise of this class was introduced in 2002 by Florida who was looking for justifying why some regions in America perform better than others. He found out a recipe that correlates with economic growth, the 3 T's approach: technology, talent, and tolerance (Florida, 2002). Therefore, life-hackers participate in this growth because they are driven by "*new ideas, new technology, and creative content*" (Reagle, 2019).

2.5 Adoption theories and models

A multitude of theories and models have been developed to find an explanation to the user adoption phenomenon especially regarding the acceptance of new technologies. All of them introduce factors that influence user acceptance (Taherdoost, 2017). Acceptance is the "*antagonism to the term refusal and means the positive decision to use the innovation*" (Simon, 2001). It is therefore upstream from this 'use of innovation' that corresponds to user adoption (Orston, 2018).

A major contribution has been brought by Davis and his Technology Acceptance Model (TAM) in 1986, which is an adaptation of the first model developed in 1975 by Fishbein and Azjen called Theory of Reasoned Action (TRA) (Sledgianowski, & Kulviwat 2008, 2). The TAM sets the two first determinants of the intention to use technology: Perceived Usefulness (PU) and Perceived Ease of Use (PEU). The former is described as "*the potential user's subjective likelihood that the use of a certain system will improve his/her action*" and the latter is "*the degree to which the potential user expects the target system to be effortless*" (Lai 2017, 6). Figure 10 below shows the first modified version of the TAM imagined by Davis, Bogozzi, and Wharshaw (1989).

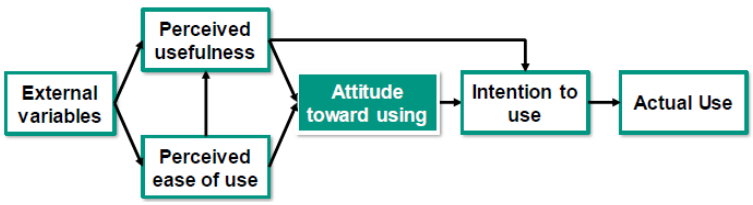

Figure 10. The first modified version of Technology Acceptance Model (TAM) (Davis, Bogozzi, & Warshaw 1989)

The TAM tackles the user's beliefs of PEU and PU of the technology but also external factors that vary according to the type of technology studied (Sledgianowski, & Kulviwat 2008, 2). For instance, the system experience, level of education, and age (Burton-Jones, & Hubona 2006). Like any model, some pain points have been identified in the TAM such as when the "*desire to use a system is for self-indulgence or entertainment of the user*" (Reneau 2013, 20). Overall, intrinsic motivations are not integrated into the model (Taherdoost 2017, 963) and the Consumer Acceptance of Technology (CAT) rectifies this oversight by incorporating cognitive and affective factors (Kulviwat et al., 2007). The CAT model explicitly considered the way individuals think and feel (AlSaleh, & Thakur 2019, 181). On the one hand, cognitive determinants regroup PU, PEU as well as Relative advantage. The latter is described as "*the extent to which an individual believes that a piece of technology is superior in some way to what it is intended to supersede*" (Rogers, 1983). On the other hand, affective elements integrate notions of Pleasure, Arousal, and Dominance. The first one focuses on the degree to which someone feels joyful, happy, good, or satisfied in a certain moment (Menon, & Khan 2002). The second notion refers to the mental alertness that allows an individual to focus all his/her attention on the element in question (Thayer 1989, 6). The last one is associated with the feeling of influence or power over individuals or situations (Mehrabian, & Russell 1974).

The CAT model added a social dimension because several studies have demonstrated that it is one of the most important determinants that impact consumers' acceptance to use high-technology innovations (Venkatesh, & Morris 2000). Indeed, faced with innovation uncertainty, potential users prefer to collect opinions from their peers or social networks before making an adoption decision (Burkhardt, & Brass 1990). Figure 11 below is therefore a new version of the CAT model called CATS.

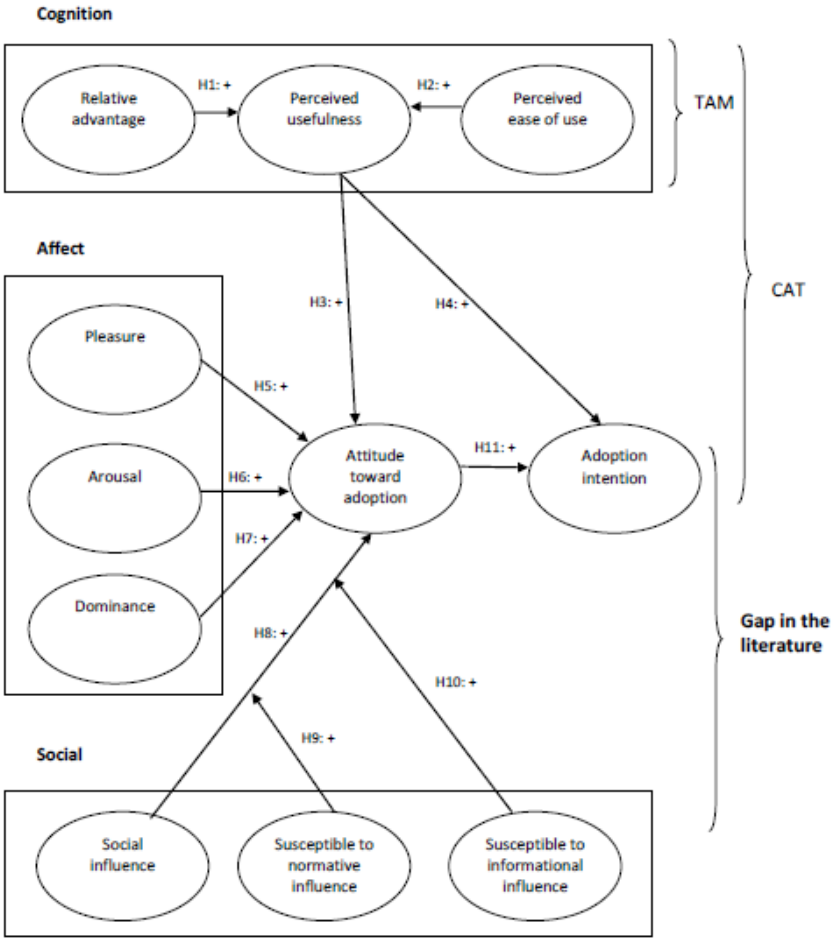

Figure 11. Proposed theoretical model: CATS (AlSaleh, & Thakur 2019, 186)

Then, other research has focused on the user experience (UX) and determinants impacting the intention to use and willingness to adopt. Topolewski et al. (2019) based their empirical study on UX experiments with users of the Jaxber app. They developed a UX holistic model (Fig.12) as a multilevel formative structural equation model. There are three dimensions: Business (a combination of the Economic and Technological facets), Human (mix of the Emotional and Cognitive facets), and Social (with the Empathic and Interpersonal facets). Each UX facet is composed of three or four factors called UX properties. All UX properties and dimensions impact directly the INTENTION (to use) entity. The latter is based on three indicators: Convincingness, Willingness and Recommend. To sum up, the three dimensions (Business, Human, and Social) positively influence the intention to use and willingness to adopt.

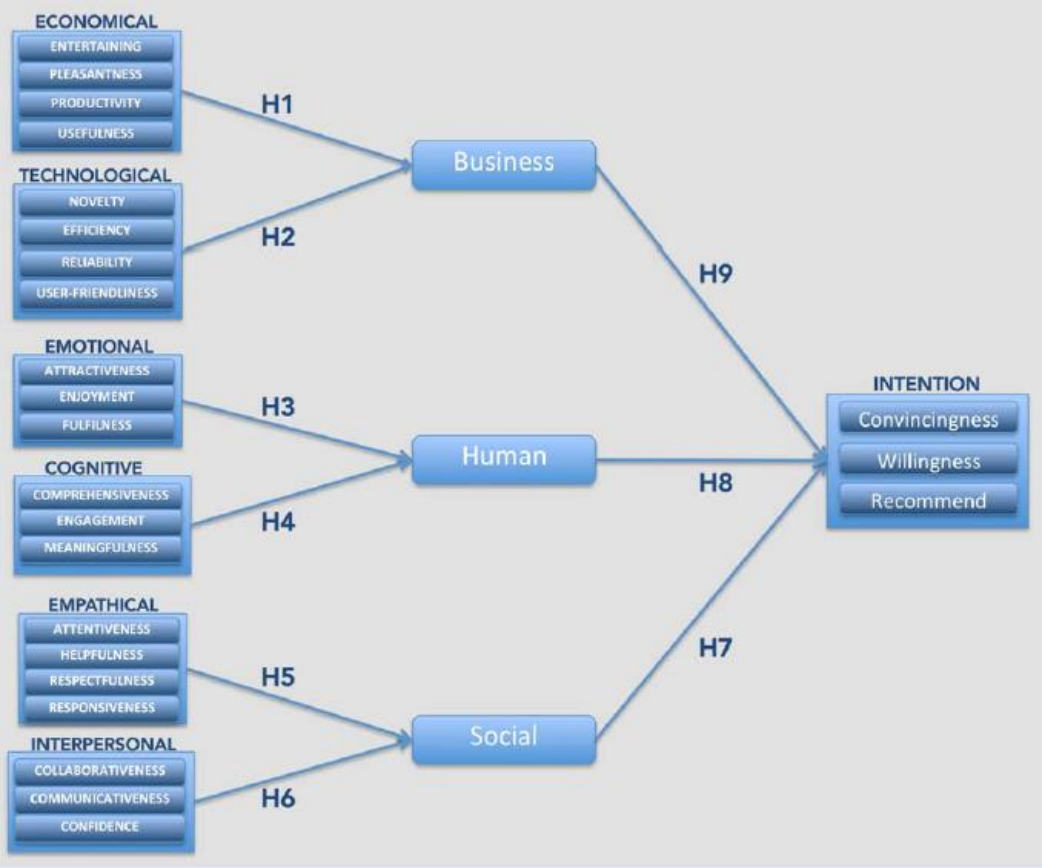

Figure 12. UX-Adoption Model (Topolewski et al., 2019)

Finally, although most of the adoption models have studied new technologies or innovations acceptance, few others have been adapted to other domains such as body hacking (synonym of biohacking). Giger and Gaspar (2019) investigated the intention to practice body hacking and proposed a theoretical framework to identify the motivational factors (Fig.13). The framework combines seven factors that may work as body hacking behavioural intentions determinants. It is the only one found on Google Scholar by the author that offers an adoption model related to the body hacking subject. On the one side, some factors are really different from the classic

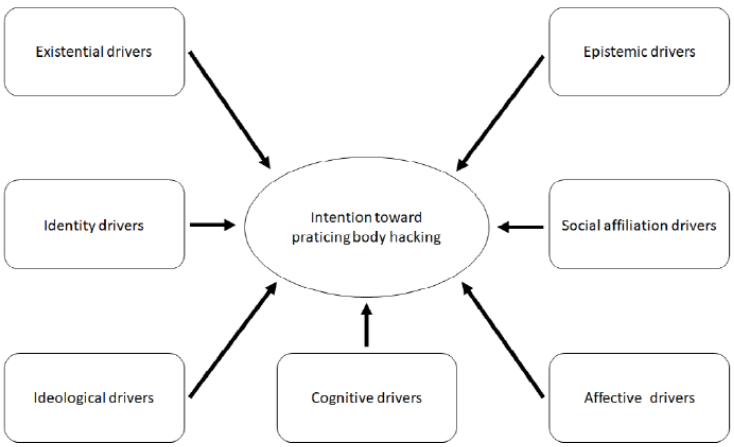

Figure 13. Theoretical drivers of the intention towards practicing body hacking (Gaspar, & Giger 2019, 309)

adoption models such as existential drivers regrouping the fear of death that underlies many human behaviours (Burke, Martens, & Faucher 2010) but also the human nature conception of people who are reluctant to modify the body as cyborgs do (Wilson, & Haslam 2013). On the other side, some other determinants are identical such as cognitive drivers related to PU, PEU but also perceived behavioural control (Ajzen, 1991) and perceived risks (Gaspar, & Giger 2019, 312).

2.6 Identified Gaps

The workplace is shaped by the modern and capitalist economy, pushing workers to reach the company's objectives, work longer, be more efficient, and always connected to his job even from home. Whereas employees are impacted badly, three strategies have been developed to solve these problems: ergonomic workplace design, cognitive enhancement, and efficiency enhancement methods. All together they pursue the well-being of the employee but none of them are self-sufficient. In other words, there is a lack of a holistic approach to get the big picture of how to fully support working persons. For instance, ergonomic workplace tackles audio, light, temperature, and body posture to reduce pain and physical health problems due to poor ergonomic environment. However, this strategy is limited because it doesn't bring biochemical support to the employee through the nutrition aspect that has been included in the cognitive enhancement strategy. In turn, the latter lacks an emphasis about the workflow and time management technics that help for cognition functions. The efficiency enhancement method regroups all these concepts to do tasks right but miss the elements of ergonomic workplace design and cognitive enhancement strategy.

Furthermore, in order to implement these strategies, the decision to change must be born. Indeed, the employee has to be conscious of the opportunities available to him/her to improve his/her well-being. The individual should adopt this change willingly and many determinants will influence the process. The CATS adoption model embraces a wide range of factors - cognition, social, and affect - but a

deepening miss in the last category. Affect regroups notions of ‘pleasure, ‘arousal’, and ‘dominance’ but the notion of ‘emotion’ would have been relevant to incorporate. In fact, people that make the decision to adopt something like a movement or a strategy, are also driven by their curiosity and interests. A strategy would be adopted if it raises the interest of the person who hesitates to take this decision.

2.7 Research Framework

The author identified a lack of researches about biohacking at work. Biohacking starts to gain popularity among people outside DIY biologists, cyborgs, or life-hackers communities because it targets health/well-being and performance. These two notions interest the work environment and the author thinks biohacking has a potential within the work organization and workplace. Three strategies have been designed independently of each other, but the author saw a synergy between them and similarities with the biohacking movement. Table 7 regroups all elements from each strategy that is part of biohacking at work.

Table 7. Strategies for a common goal: biohacking at work

Strategy	Element	Description	Source
Ergonomic workplace design	Audio	Reducing noise levels decrease work stress and distractibility.	Fairbrother, & Warn 2003
	Light	Light helps to reduce work stress because high levels of glare and minimum lighting can cause eye strain.	Sutton, & Rafaeli 1987; Aaras et al. 2001
	Temperature	Extreme heat can generate mental depression and extreme cold can alter mental capacities that may lower performance and higher absenteeism.	Clark, 2002; Smith et al. 2000
	Body postures (Physical stress management)	'Human' factors aim for erasing all potential overload muscles by promoting dynamic work, showing correct natural postures, and adapting work surface height.	Fernandez, & Goodman 1995
Cognitive enhancement	Meditation (Mental stress management)	Meditation has many psychological and physiological benefits such as reduced anxiety and depression or lower oxidative stress.	Manocha et al. 2011; Schneider et al. 1998

	Nutrition	Balanced nutrition with enough nutrients participates to well-being and avoid chronic inflammatory, anxiety, and depression.	Sovijärvi et al. 2019; Foster, & McVey Neufeld 2013
	Sleep	Sleeping enough (> 6 hours) participates to workers' productivity. Naps can erase performance-deteriorating effects caused by sensory overload.	Hafner et al. 2017; Mednick et al. 2002
	Sport	Active workers perform better in cognitive tasks than sedentary workers. Team sports increase team spirit and communication.	Ratey, & Loehr 2011; Cogein et a. 2010
	Electricity / Magnetism	TMS increases excitability of the motor cortex that leads to better performance in procedural learning tasks.	Bostrom, & Sandberg 2009
Efficiency enhancement	Flow	The worker will experience a time of peak emotion and performance, where everything else around is shut outside consciousness. The task will become meaningful and push the person to his/her competences' limits.	Sovijärvi et al. 2019

Elements can be either directly implemented at work like reaching the flow state to be immersed in the task or will require some arrangements such as changing lights or allocating a room reserved for physical activities or meditation during breaks. However, biohacking at work is not only a mix of these three strategies. It is also directly linked to biohacking with two aspects: quantified-self (QS) and habits / mindset. On the one hand, here QS is seen useful through self-trackers such as wearable devices. Indeed, they cannot be mandatory for employees, but these gadgets that generate data can be useful to analyse the physical effects of changes implemented at work. On the other hand, the employee has to be consistent (mindset) and long-term oriented (habits) to testify positive results on his/her well-being and performance. Therefore, the author suggests a new strategy, biohacking at work (Fig.14), that will raise the well-being and performance of employees.

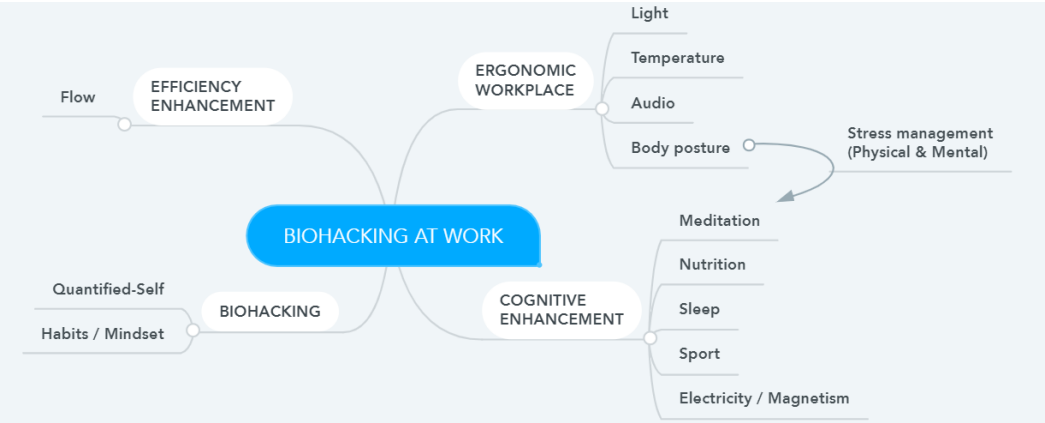

Figure 14. A Holistic view of Biohacking at work

Like any strategy that calls for change, implementing biohacking at work requires the action of adoption from employees. Therefore, the author suggests a new adoption model combining determinants that will lead to the biohacking implementation at work: The Biohacking User eXperience Model with Causal Effect on Adoption (Fig.15).

In this study, UX Facets and UX dimensions represent users' expectations while UX (second-order construct), which represents the user's perception of satisfaction, impacts the "Intention to Adopt", which is supported by three different factors, namely: (i) "Convincingness to adopt Biohacking at Work practices"; (ii) "Willingness to use Biohacking at Work practices"; (iii) "Readiness to recommend Biohacking at Work practices to colleagues". These factors are expected to reveal the level of users' potential adoption. Therefore, the above-mentioned Biohacking at Work UX model including the causal effect on adoption is based on two existing validated models: (a) the TAM model (Davis et al., 1989); (b) partly the UX-Adoption model (Topolewski et al., 2019). Compared to the TAM model, this combined model has a lower granularity level in order to better understand their potential impact on UX through the composition of UX facets and dimensions. UX dimensions, facets, and properties are related to the specific context of Biohacking at Work practices to be evaluated. As shown in Fig.15, the Biohacking at Work UX model is composed of UX properties (formative factors) feeding UX Facets (higher-order constructs) forming the Biohacking at work UX (higher-order construct), which impact the adoption potential via the "Intention-to-Adopt" and its three reflective factors.

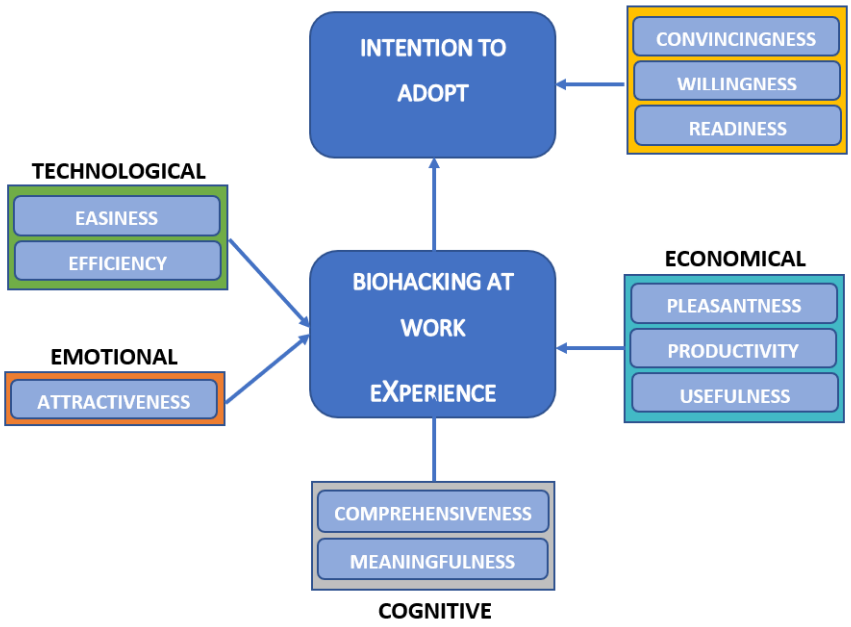

Figure 15. Biohacking at work UX Model & Causal Effect on Adoption

Regarding the UX model used in this study, there are two dimensions, namely: Business that is composed of the Economic and Technological facets, and Human that is composed of the Emotional and Cognitive facet. UX facets are composed of several properties (factors) as shown in Table 8 below.

Table 8. Description of factors

UX Property	Description
Usefulness	Degree to which the Biohacking at Work allows users to get more benefits than side effects.
Pleasantness	Degree to which Biohacking at Work practices are perceived as pleasant-to-use.
Productivity	Degree to which Biohacking at Work practices are perceived as bringing an increase in task achievement.
Efficiency	Degree to which Biohacking at Work allows users to feel healthier.
Easiness	Degree to which Biohacking at Work practices are perceived as easy-to-use.
Attractiveness	Degree to which Biohacking at Work practices are perceived as emotionally attractive.
Comprehensiveness	Degree to which Biohacking at Work practices are comprehensive enough for potential users.
Meaningfulness	Degree to which Biohacking at Work practices are perceived by users into meaningful outcomes.

Compared to the TAM model, the Usefulness factor represents the “Perceived Usefulness” (PU) while the Easiness factor replaces the “Perceived Ease of Use” (PEU). Originally, the parsimonious nature of the TAM model was conceived for

Technology Acceptance with the limitation of neglecting other external factors. While PU and PEU are pretty well-identified properties of UX, Pallot, and Pawar (2012) have studied a holistic model of UX confirming its multidimensional and multifaceted characteristics. Therefore, one can deduct that other factors or UX properties influence the intention to use or adopt a proposed solution. Topolewski et al. (2019) have statistically validated a UX based Adoption model that takes into consideration all UX dimensions and facets relevant to the specific context of the proposed solution. For the above-described Biohacking at Work UX based Adoption model: (a) Pleasantness and Productivity UX properties together with Usefulness form the economical facet; (b) Efficiency and Easiness properties form the Technological facet; (c) Attractiveness property forms the Emotional facet; (d) Comprehensiveness and Meaningfulness properties form the Cognitive facet.
This customized Biohacking at Work UX based Adoption model will have to be statistically validated in a future empirical study having more than the minimum 100 respondents that is beyond the scope of this present exploratory study.

3 Methodology

3.1 Research Context

After demonstrating the benefits of raising employees' well-being for the sake of a firm's economic situation, while also presenting a holistic approach of the biohacking at work strategy that tackles well-being as well as performance, the author was interested with studying the business potential of practicing biohacking within the workplace. It focuses especially on offices where improvements can be implemented by both employees (self-changes) and employers (layout of the environment). The author thinks that the topic of biohacking is legitimate within the workplace given that it consists of improving daily life habits without specifying the private or professional setting. Moreover, the rise of firms selling products and services related to biohacking (See section 2.2.5 Business potential of biohacking) shows a growth potential of the market. Finally, the idea of business potential is often related to productivity. The author will analyse the collected data from the survey to check if

this notion is present in the respondents' justifications while talking about biohacking at work.

The purpose of this thesis is to explore the business potential of biohacking implemented at work by studying the existing knowledge, interests, perceptions and experiences workers have concerning biohacking, but also by examining topics (e.g. sports, nutrition, light) already personally implemented to target afterwards the ones that will increase the degree of readiness to adopt biohacking at work. In order to answer correctly to the below-mentioned research questions, the author decided to conduct an online survey:

1.1 What are the topics linked to biohacking that can be implemented at work, in order to improve the overall well-being and performance of workers?

1.2 What are the perceived benefits and drawbacks of Biohacking?

1.3 What are the factors impacting employees' adoption of Biohacking at work?

The author esteems these research questions are complete, well defined, and clearly delimited of what the survey will bring as data. Answers of the first question will confirm or not the author's holistic view of the biohacking at work. It provides an overview of what respondents personally implement in their daily life (e.g. sports, nutrition, lighting) in order to show which topics related to biohacking have higher chances to interest employees to change work habits at the office. The second research question is directly related to respondents' experiences and opinions. Their perceived benefits and drawbacks will be compared to the ones identified in the Literature review. Then, the third question is about understanding what would be the factors of biohacking adoption at work and how much they are different from the ones identified in the existing adoption models. Finally, the overall level of convincingness of biohacking benefits at work, the willingness to apply biohacking practices as well as the readiness to recommend them to colleagues should allow evaluating the degree to which employees could adopt Biohacking at Work and could become the basis for future research.

3.2 Research Approach

The research philosophy reflects the particular view adopted by the author about the link between the knowledge and the process by which it is developed (Saunders et al. 2008, 108). Although different philosophies exist, the pragmatist's philosophy has been chosen especially for this thesis. Indeed, while designing the research method, the author placed in the limelight the research question "*What would be the degree of people's adoption and willingness to apply biohacking at work?*". The latter follows neither an interpretive nor positivist philosophy and suggests a continuum position rather than an opposition. Tashakkori and Teddlie (1998) argue the researcher should study what seems interesting, has value, and can be deeply appropriated. Moreover, he/she should be able to "*use the results in ways that can bring about positive consequences within* [his/her] *value systems*" (30).

Then, the author adopted an abductive approach that is situated between deductive and inductive approaches. Indeed, the deductive perspective belongs usually to the positivist philosophy and the inductive one is more related to interpretivism (Saunders et al. 2008, 124). Therefore, since the author has a pragmatist's philosophy, it makes sense that the approach is mixed. Whereas the deductive approach is based on scientific research with a fixed theory, the inductive approach is about designing an own theory after analysing data from a survey in the case of this thesis. The author didn't build from scratch a research framework but re-adapt existing ones that deal with degrees of adoption and its determinants. In other words, the author introduced the existing models (See 2.5. Adoption models and theories) that have been afterwards mixed together and used for the design of the research framework of the thesis (Fig.15).

3.3 Research Design

The nature of the author's research design has been identified as exploratory for several reasons. First of all, the subject of interest is relatively new (creation of biohacking movement in 2008) and after a literature search on Google Scholar, the author concluded empirical studies about biohacking are limited (469 publications published in 2019) but especially biohacking at work (333 results in 2019). The author

was therefore even more motivated to deep dive into a topic lacking research, information, and explanations in order to "*seek new insights; to ask and to assess phenomena in a new light*" (Robson, 2002, 59). Then, the author confirmed an interest in biohacking through professional experience in a firm that promotes and experiences biohacking practices in the work and at the office as a company culture. Experts' interviews have been conducted within the enterprise - independently from this study - to get a big picture of the movement and to collect opinions about the overall potential of biohacking. This initiative from the author supports the decision to explore the topic of biohacking and specially adapted to the workplace. Since the author acted as a traveller or explorer (Adams, & Schvaneveldt 1991), it gives certain flexibility in the exploratory research by first adopting a broad focus then adapting the direction according to new data and finally narrowing the research. Finally, the last characteristic of the exploratory study is about conducting a focus group interview that would suggest a single qualitative research method with few respondents (Hair, Bush, & Ortinau 2002). However, the author didn't proceed with a focus group interview but still chose to adopt partly a qualitative approach with a small sample.

The research method relies on an online survey that is generally used for exploratory research (Saunders et al. 2008). Usually, this strategy is chosen for collecting a large amount of data analysed afterwards quantitatively (144). Nonetheless, the author thinks quantitative and qualitative techniques but also analysis procedures don't work separately and should coexist within the survey analysis. Therefore, the author implemented a mixed-method research that brings a certain rigor with the quantitative part and subjectivity with the qualitative part (Olsen, 2004; Creswell, 2007). According to Auer-Srnka and Koeszegi (2007), there are two mixed-methods design categories: two-studies design and integrated design. The latter is the most recent approach since it makes the combination of qualitative and quantitative analysis within the same study (ibid., 2007). Therefore the design chosen by the author for the survey analysis is the Integrated design.

Furthermore, according to Creswell (2003), different forms of mixed methods (MM) exist and lead to transformative, sequential or concurrent strategies. In the exploratory study conducted, the author based the research approach on MM

Concurrent Strategy with the qualitative questions embedded into the quantitative one (ibid., 2003). The quantitative instrument is a mix of descriptive and bipolar questions as well as demographic questions at the end of the survey to set the respondents' profile. Each bipolar question is followed by an open-ended question to give a proper justification of respondents' ratings. The author implemented a combination of Concurrent Nested Strategy (CNS) where one of the findings complements the other one and Concurrent Triangulation Strategy (CTS) where collected data are compared.

3.4 Data Collection

First of all, while planning the research, the author decided for a cross-sectional study which acts as a "snapshot" taken at a specific time because of the very nature of the topic being studied. Indeed, Biohacking generates different reactions within the society from fears and concerns about grinders to the admiration of Silicon Valley start-ups applying biohacking practices. This movement is fast-changing so the findings of this study may be invalid in some years. Besides, cross-sectional studies are often used in survey strategies according to Robson (2002) so the survey appears relevant for the data collection.

The online survey has been created in December 2019 through Google Forms which offers certain flexibility in the design of questions and easiness to share it with a clickable link for respondents. While finishing the BRAINEFFECT internship, the author opened the survey to colleagues who have in general a good understanding of biohacking. Most of them practice it in their personal life but also in the professional context. The author was interested in verifying how diverse the definition of biohacking is for all and to get some insights about their biohacking habits. Then, during the following weeks, the link of the survey has been shared with external persons from the firm. These individuals have been selected on a common characteristic: having a job or having a work experience in offices previously. Unlike BRAINEFFECT's employees, the other respondents don't have knowledge about biohacking and don't specifically pursue an objective of improving well-being and performance. This portion of the sample studies brings certain neutrality and objectivity in the judgment to adopt biohacking practices. The author judged this

mixed sample relevant to collect findings from respondents knowing and practicing or not biohacking because it broadens the answers panel, representative of workers in offices who have different interests, opinions, and objectives. The survey was opened until reaching a minimum of 30 answers that happened mid-February 2020. The author didn't want to collect a large sample N=100 because the survey doesn't follow a quantitative approach completely and this low sample (N=31) allows a qualitative data collection with open-ended questions that can be analysed accurately and precisely.

The survey regroups 29 questions (Appendix 1.) thus the last seven ones are demographic questions to identify respondents' profiles and 6 of them are justifications of their ratings (e.g. Q4 bis). Naturally, the quantitative and qualitative questions reflect the research framework of the study. Therefore, the list below shows the questions - with a short description - classified by the same colours used for the Research Framework. For example, orange questions correspond to the UX property 'Attractiveness' within the Emotional part of the Research Framework. To differentiate the qualitative questions to the quantitative ones, the author underlined qualitative questions:

Q1. Biohacking own definition
Q2. Biohacking own factors
Q3. How much are you a Biohacker
Q4. How interested about Biohacking
Q4 bis. Bipolar explanation
Q5. How easy/difficult to recognize Biohacking practices in your daily life
Q5 bis. Bipolar explanation
Q6. How often are you associating a healthy action to biohacking practice
Q7. How different own factors from Biohacking diagram
Q7 bis. Bipolar explanation
Q8. Opinion about Biohacking diagram
Q9. Biohacking diagram personal level of implementation
Q10. Share a positive experience
Q11. Share a negative experience
Q12. Biohacking benefits
Q13. Biohacking drawbacks
Q14. Convincingness about the benefits of applying Biohacking practices at work
Q14 bis. Bipolar explanation
Q15. Willingness to apply Biohacking practices at work
Q15 bis. Bipolar explanation
Q16. Readiness to recommend biohacking practices to your colleagues at work
Q16 bis. Bipolar explanation

Q17-Q23. Demographic questions

On the one hand, quantitative questions set the scene for the study. They are structured and offer pre-determined response options in the survey (Hair, Bush, & Ortinau 2002, 211). Descriptive research questions often begin with “How much, often…” (Q3) or “What is” (Q15) to be used to quantify one variable like “Biohacking practices” (Q6). For the author’s survey, quantitative questions are a mix of bipolar questions with matrix and demographic questions. The advantages of quantitative questions are the easiness to collate data and the possibility to study at once all of them by building charts to have an overview. However, these question types present the disadvantage to focus on numbers and some topics such as Biohacking, are complicated to simply quantify (Devault, 2019).

On the other hand, the qualitative questions bring a certain depth to the collected responses. Indeed, the open-ended questions (Q1) and justifications that follow bipolar questions (Q4 bis) allow to collect a detailed amount of primary data from a relatively small sample that the author’s survey has (Hair, Bush, & Ortinau 2002, 213). The author proceeded with a tag cloud analysis to extract the most mentioned terms within the answers (Waldner et al. 2013) for qualitative analysis. Moreover, the author can obtain preliminary insights about motivations, interests (Hair, Bush, & Ortinau 2002, 213) and even factors that influence the adoption of biohacking within the workplace from the respondents. Besides, sentiment analysis was conducted to be able to create a semantic scale from quantitative and qualitative data.

The sample is too small, and the nature of the qualitative questions results in a lack of true reliability and possible generalizability to draw conclusions for all workers. However, qualitative questions give the chance to identify a business opportunity (ibid., 2002), exactly what the author looks for with practicing biohacking at work.

4 Results

4.1 Respondents' profile

First and foremost, the demographic questions allow setting the profile of the 31 respondents. Data shows the majority of them are men (almost 2/3) and are between 18 and 25 years old (3/5). Most of the persons are German (48 %) or French (21 %) and at 45 % work for BRAINEFFECT. In general, there is a variety in the sector of activity and the functions within the company (marketing, sales, finances…). Finally, 2/5 work there for more than 1 year and 1/3 less than 6months.

If we took into consideration BRAINEFFECT employees who received the survey first and represent almost half of the surveyed people, it is normal to see that most of the respondents are between 18 and 25 years old because it is the average age within the German enterprise. Moreover, the author is also in this age group so her social and professional networks focus on people aged 25-30 years old. Then, the nationality repartition proves that BRAINEFFECT employees participate in it and the French origin of the author is also a determining factor. Ultimately, the heterogeneity of the sample is reflected in activity sectors and functions at work which is a good base to collect different feedbacks about biohacking adoption within the workplace.

4.2 Biohacking practices and the holistic view

The respondents of the survey give plenty of topic ideas related to biohacking in general (Q2) and which practices they personally implement (Q9). Besides, they give their own definition of biohacking (Q1) and their opinion about the diagram of the survey exposing the topics related to biohacking (Q8). Overall, collected data from these four questions will answer the research question 1.1.

Before talking about biohacking practices, the author used a tag cloud to analyse the main terms mentioned to describe biohacking. At first glance, biohacking appears to bring a positive impetus with 71% of the respondents writing down synonyms of "optimization" or "improvement". Then, they confirmed that biohacking encompasses in priority "body" (12 mentions) and then "mind" (7 mentions including

substitutes). Overall, the author's hypothesis - described in the Literature Review part 2.2.3 - about what people are looking for with biohacking (well-being and performance) is validated by respondents' answers: "perform(ance)" (x12), "well-being" (x2) and all its synonyms (feel better, health(y), quality of life, life quality).

Then, respondents had several occasions through different questions to talk about what biohacking deals with. The first qualitative question serving as an introduction to the survey invites unintentionally people to list topics related to biohacking, but it is the second one that asked explicitly the persons to give bullet points. The difference between answers to these two questions is that sub-categories of biohacking discussed in the Literature review are implicitly described. Indeed, the DIY biology is mentioned through the use of "DNA" or "genetic code" like the answer of this respondent shows: "*Biohacking is tapping into someone's own genetic code and manipulating the specific codes to create features specific to the hackers wishes*". The cyborgs and grinders category (the hard version of biohacking) is everything linked to technologies: "hard- & software", "tools" and "gadgets". Finally, the soft version of biohacking related to life-hacking is mainly considered: "*Knowing your body and supporting it with […] tips and tricks to generate better sleep, more focus...*".

Globally, all the topics related to biohacking within the holistic view of biohacking at work introduced by the author have been presented. In the cognitive enhancement branch, meditation, nutrition, sleep, and sport were mentioned most of the time but the electricity/magnetism topic wasn't. This is reflected in the poor level of implementation of it asked in question 9 with 91 % of "never" and "rarely" ratings (Appendix 2.). Then, in the ergonomic workplace brand, respondents are conscious that biohacking is not only a question of self-improvement because surroundings play also a role: "*Biohacking is the practice of tracking/measuring and optimizing your body, mind, and environment*". Light and Temperature - two elements of the ergonomic area - have been highlighted: "blue light filter" and "cold exposure". Moreover, the efficiency enhancement branch dealing with the flow state is reflected across its semantic field: "concentration", "focus" and "attentiveness". Ultimately, the biohacking brand composed of Quantified-Self and Habits / Mindset, are both named: "*implementing healthy habits to your daily life*", "mindset" mentioned 3

times, “quantified-self” as well as its synonyms “tracking”, “measuring”, “analysing data”.

To sum up, the mind map designed by the author to represent a holistic approach of biohacking at work is validated by the respondents’ answers. However, question 8 gives the chance to individuals to make suggestions of modification. A really interesting point popped up; interconnections and networks within the diagram: “*The diagram summarizes biohacking pretty good even though it doesn't show that all categories are interconnected as well. Sport has an influence on your stress management flow, sleep in a positive and in a negative sense.*” but also “*The diagram does not depict interdependencies between different themes, a network would be better* […]”. Therefore, this suggestion would bring a smart complexity in the author’s diagram but like that, people would realize that biohacking is everywhere: “*I didn’t expect the biohacking being so present in our lives*”.

4.3 Perceived benefits and drawbacks of biohacking

The benefits and drawbacks of biohacking were tackled with the survey (Q10 to Q13) and it will help to answer the research question 1.2. The author wanted to compare the positive and negative impacts of topics related to biohacking identified in previous work with the ones perceived by the surveyed people. Table 9 below regroups each topic exposed to the respondents to make a comparison.

Table 9. Perceived benefits and drawbacks of biohacking compared to previous work

Topics	Literature Review	Respondents Perceptions (+)	Respondents Perceptions (-)	Matching
Nutrition	Well-being, reduced anxiety & depression	Energetic, productive, improved performance	Allergies, Food obsession	NO
Sleep	Higher productivity & performance	Feeling better, positive mindset	Sleeping worse, didn't work (with melatonin)	NO
Meditation (Stress management)	Reduced anxiety & oxidative stress	More relax before stressful moments	Making sleepier, dependency	YES
Sport	Higher cognitive performance, decreased depression & stress	Feeling better and healthier, energized	ø	YES/NO

Electricity / Magnetism	Brain simulation can accelerate learning tasks	Not mentioned		ø
Audio	Lower work stress & distractibility	Better concentration, Better sleep with Beta waves	Didn't work (Music before sleeping)	YES/NO
Light	Lower work stress	Awake, alert, greater level of productivity	ø	NO
Temperature	Extreme heat = mental depression / Extreme cold can alter mental functions, lower performance & higher absenteeism	Energized, helping not to get sick (cold shower or ice bathing)	Getting sick, didn't work (cryotherapy)	NO
Body postures	Erasing overload muscles	Not mentioned		ø
Flow	Peak performance and emotion, tasks become meaningful and pushes to competences' limits	Higher motivation, Easy to do tasks	ø	YES
Habits / Mindset	Consistent (mindset), Long-term oriented (habits)	Sleep tracker part of routines, Habits help to implement biohacking in daily life	Feeling guilty if habits not done	YES
Quantified-Self	Useful data from wearables devices, empowerment	Awareness value of moving, sleep tracker improve recovery	Insomnia, Over-tracking, Dependency, Overdoing	NO

The Matching column gives a preview of consistency (YES) or not (NO) between what was found in external studies and what was mentioned in the survey. When half of the benefits from the literature review were referred in the survey, "YES/NO" is written and the symbol "ø" means the comparison can't be made because a certain topic wasn't considered by the respondents.

Overall, there are more topics perceived differently by people compared to the previous work than topics perceived identically with the same benefits. The reason why some topics don't have a match is that they were not thought of in the same way. For instance, the temperature in the literature review was about the ergonomic workplace and in the survey, it was about personal action with a cold shower, ice bathing, or cryotherapy.

Furthermore, the benefits and drawbacks of self-experimentation listed in the Literature Review can be also compared to the ones associated with biohacking and mentioned by the respondents (Table 10 below).

Table 10. Perceived biohacking benefits and drawbacks compared to previous work

+/-	Topics	Literature Review	Respondents Perceptions	Matching
+	**Active participant**	Acquiring knowledge	*"Important to know ourselves better."*	YES
	Control health	Better control of health	*"I can take control of my health and address specific issues with specific targeted solutions or overall actions that improve my health."*	YES
	Confidence	ø	*"Self-confidence"*	ø
	Body consciousness	ø	"[…] *being alert to signs of your body when it needs to rest* […]", "I*t's important to have conscious of our body*."	ø
-	**Question of ethics**	Grinders' perception of the human body compared to a machine	"*I think it is risky to change what the nature did. I'm worried about the future of biohacking.*"	YES
	Push limits of the body	Obsessive behaviours to always want more and do better. Unsafe manners of doing with side effects.	"*overdoing it, causing your body too much stress* […]". "*I sometimes don't like the competitive side, always having to be better than everyone else and* […] *than you were yesterday*."	YES
	Self-focus	ø	"Too much focus on yourself"	ø
	Dependency	ø	"*Don't live with it every day. The body will acclimate and not being able to live well without it*."	ø
	Over-estimation	ø	"*Overestimate the influence of anything.*"	ø
	Time-consuming	ø	"*You have to use a lot of your time to do biohacking.*"	ø

Globally, most of the positive and negative points about self-experimentation mentioned in the literature review are also communicated in the survey and they fit together. Respondents didn't tackle all of them (therefore not listed above) but addressed other interesting topics like "Dependency" or "Body consciousness".

4.4 Factors impacting employee's adoption of biohacking at work

Within the survey, the author designed a kind of biohacking at work experience to test the UX properties from the Research Framework of the study and to answer the research question 1.3. The UX properties coming from existing adoption models

(TAM (Davis et al. 1989) and UX Facet Model (Topolewski et al. 2019)) represent factors impacting employee's adoption of biohacking at work. The eight UX properties could be analysed with questions 1 to 13 (except Q7 and Q7 bis) and the list of questions (See 3.4 Data Collection) shows which ones refer to a specific UX property. Given that quantitative and qualitative questions are mixed, sentiment analysis was made for the qualitative parts in order to simplify the creation of a semantic scale (Fig.16).

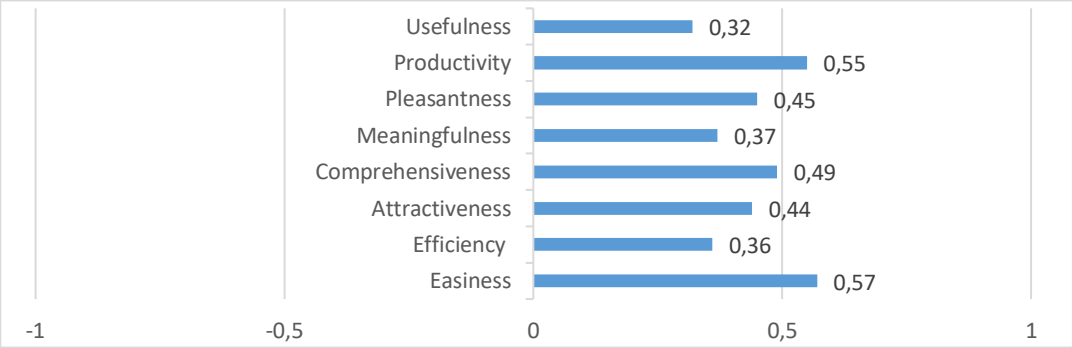

Figure 16. Biohacking at work experience with UX properties

If we have a look at the Easiness UX property, comments from respondents give reasons why biohacking is not that easy to practice: "*For most of it, it is really hard to start. You have to do a lot of research to know how it works*", "*The actions or habits I have integrated in my daily life is what I learned after I did some research about biohacking. So, I didn't know them before*". However, another surveyed person brought a neutral opinion that is summarizing the point about "Easiness": "*Biohacking sounds harder than it is. Sometimes things are already working as a biohack even though it doesn't feel quite hacky.*"

Globally, ratings obtained for these 8 UX properties are positive (above 0) but not extremely close to 1. Trying to be as much objective in the sentiment analysis neither with an optimist nor a pessimist approach, the author thinks the results are accurate and reflect the general feeling emerging from biohacking. In other words, biohacking is not yet well-known within the society and developed sufficiently to give all the keys to people to feel confident with this movement (meagre UX properties scores).

4.5 Degree of people's adoption about applying biohacking at work

The previous parts answering the 3 minor research questions, serve to introduce this last section that deals with the major research question of the study. The degree of people's intention to adopt biohacking at work depends on three

elements: Convincingness, Willingness, Readiness (Topolewski et al. 2019). The author could directly collect data with three bipolar questions and its justifications (Q14, Q14 bis, Q15, Q15 bis, Q16, Q16 bis). The author proceeded with the same method as for the UX properties analysis: a sentiment analysis to be able to combine qualitative findings with the quantitative ones within a semantic scale. The bar chart below (Fig.17) shows the scores of the three factors.

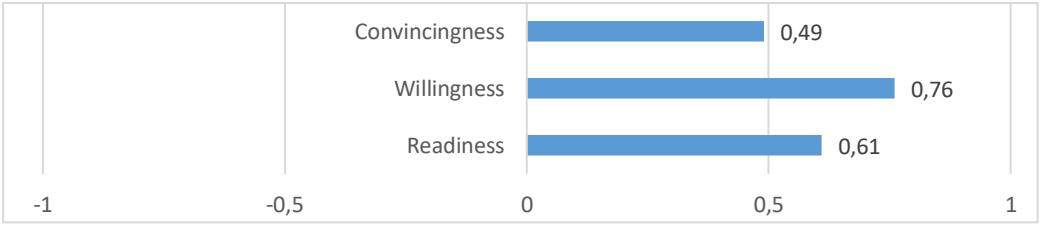

Figure 17. Causal effect: degree of adoption

First, the author asked how convinced are the respondents about the benefits of applying biohacking practices at work. Within the justifications of this bipolar question, terms of "efficiency" and "productivity" were often reported "[…] *it can improve productivity and efficiency for the whole team*". Some respondents are convinced because they already implement biohacking practices at work: "*I am starting the day with a cold shower and some sports. At work I start with a bulletproof coffee, using working hacks for more concentration, ... and track it with an oura-ring and a smart watch*" and the benefits even continue after for others "*It helps me to stay healthy and focused in work but also motivated. Even after work I feel those benefits*". Besides, some people are mitigated by certain biohacking practices at work "*there are some good hacks* […] *but some forms are a bit impractical for example power napping when there is no space to nap*" but some others are really optimistic about biohacking potential "e*specially in office work, the body and mind are often not taken care of enough. Sitting all day, looking into a computer etc. Biohacking can help prevent and tackle so many problems, every office worker has*".

Second, the author was interested to know the level of willingness to implement biohacking at work. Efficiency and productivity are reasons again mentioned by the respondents but also performance, concentration, and energy. However, this time health and well-being appeared "*I'm willing to try such practices if they could make the work healthier*" but also the notion of the ergonomic workplace through lights and body postures "*To feel better every day, protect my eyes from blue lights, protect my back from too much sitting…*". Overall, the willingness has the highest score in the bar chart (0,76) also thanks to people's interest to try and open mind: "*I think it is important to try it and see how it fits in my lifestyl*e". Nevertheless, some respondents remind that they don't want to feel forced: "*I am open to try, but I also want to have the possibility to say no if I don't like it*".

Finally, surveyed people had the last question related to the intention to adopt about recommendation level of biohacking practices to colleagues. This question deals with 'Readiness' reported in the bar chart above with a score of 0,61. On the one side, people ready to recommend biohacking to their colleagues have a caring approach "*helps me to feel better and I want my colleagues to get the same advantages*". They think it can support others "*If everyone is on the same page, it helps yourself to improve also, because everyone supports the other one*", help everyone "*It would be beneficial to everyone in the company, for employees and employers*" or decrease disagreements "*It can reduce a lot of conflicts between people*". On the other side, some respondents are reluctant to it: "*It's not a topic for everyone*", "*It is different for each person*", "*Not too familiar with the concept, so that's why I wouldn't immediately recommend*". To sum up, a respondent brought an interesting point that unifies opposite opinions: "*it doesn't matter in which level you practice biohacking. It is already simple things like routines and nutrition that make a difference. So everyone should try a few things for him/herself and his/her body and mind*".

5 Conclusion

The purpose of this study was to research the potential degree of participants' adoption and willingness to implement biohacking practices at work. The author wanted to find out which topics related to biohacking respondents are the most familiar with and would bring benefits to workers, but also which factors impact their

intention to adopt such practices at work. Therefore, the study aims to present, promote, and democratize biohacking practices at work in order to verify its business potential.

At first glance, the author looked at the existing theories to witness studies about biohacking and especially biohacking at work are missing. However, the author found enough data to lay the foundation to understand the biohacking movement: timeline, aspirations, and existing sub-categories such as life-hacking. This soft version is mainly used for the study due to its capacity to bring more benefits than possible minor drawbacks, its existing business potential that the author witnessed on the market. Besides, it is relatively easy to be introduced within the workplace.

Therefore, the author conducted in a second time a review of the literature about the current status of the workplace. Some issues were identified altering workers' well-being and performance. Three distinctive strategies were developed to tackle these issues: ergonomics workplace design, cognitive enhancement, and efficiency enhancement methods. Given that employees' psychological and physiological states influence companies' performance, the author wanted to develop a holistic approach of a strategy that deals with biohacking within the working context.

However, creating a holistic approach is not enough and in order to function, employees need to make the decision to adopt this approach. Existing adoption theories and models were designed to spot factors that influence the intention to adopt (causal effect). The author combined several of them to create the research framework of this study.

Finally, the author tested the research framework by conducting a survey in which both quantitative and qualitative questions were asked. A mixed-method methodology has been used to collect relevant data and the goal was to answer the three minor research questions to being able afterwards to answer the main research question. Results have shown that based on the responses, there is a correlation between the biohacking experience at work and the causal effect. It appears that the more satisfying the biohacking at work experience is, the higher the degree of people's adoption will be.

6 Discussion

6.1 Limitations, Reliability, Validity

This study is based on mixed-method research combining quantitative and qualitative data collected from an Internet survey. Survey research methods are generally used for causal or descriptive approaches given that surveys tend to collect raw data from a large sample (N≥100) (Topolewski et al. 2019) or even larger (N≥200) according to Hair et al. (2002, 255). One of the limitations of this study is the size of the survey because it has been completed 31 times only. However, surveys are usually used for pure quantitative data collection because questions are recorded in a precise and structured manner with pre-determined answers (ibid., 2002). The author recalls exploratory research was conducted due to the special nature of the biohacking movement, a recent phenomenon still emerging timidly outside the sphere of biohackers. Therefore, the survey didn't certainly collect enough answers but by targeting a lower amount, the author had the opportunity to include qualitative questions to justify for example bipolar questions.

Moreover, the reliability of the research that began well with a strong Literature Review, is altered by a lack of rigor in the choice of respondents for the survey. The author shared the link of the Internet survey to BRAINEFFECT ex-colleagues in order to collect valuable insights from people already implementing biohacking practices or having a minimum of knowledge. Everybody was free to answer without considering the level of implementation or expertise. Then, the link was shared to the author's acquaintances. Even if the author respected the idea to ask only workers or people who had a previous work experience, no other specific criteria were imposed to limit data collection. Therefore, the balance between respondents' profile is not always respected: 35,5 % women for 64,5 % men, 61 % of respondents are in the scope 18-25 years old and 58 % are BRAINEFFECT employees.

Finally, due to the relatively low number of observations in this study, the correlation between the biohacking experience at work and the causal effect can't be validated and inferential statistics is beyond the scope of this research. The author can only

state: it appears that the more satisfying the biohacking at work experience is, the higher the degree of people's adoption will be.

6.2 Answers to Research questions

This study aims to answer three minor research questions that will constitute the base for the main research question.

For the first minor research question, the author could validate the holistic view of biohacking at work due to the answers collected from the survey. Overall, respondents well-defined biohacking as a way to optimize the body and mind to improve their well-being and performance. Before exposing a chart that regroups topics related to biohacking, surveyed people mentioned almost all of them except Electricity / Magnetism and Body postures as physical stress management. The author feels that certain topics, like Electricity / Magnetism but also Quantified self, will have less success within the workplace since they require the purchase of gadgets and present a certain dependency. Indeed, the question about the personal level of implementation of these biohacking practices confirmed this hypothesis since these two entities are ranked at the lowest level. The author assumes that the more people implement certain biohacking practices in their personal life, the more they will be willing to apply them in the professional context. The latter puts forward the notion of environment and its ergonomics, an external element that influences workers. It is poorly included in the biohacking approach which for most respondents is a matter of 'oneself'. However, the author discovered in qualitative responses elements related such as blue lights and back pain management due to sitting. Finally, even if the holistic view of biohacking at work is confirmed by the respondents, improvements could be brought as few individuals suggested with interconnections and networks that will show an interdependency between biohacking practices.

Then, the second research question deals with the perceived benefits and drawbacks of biohacking. The more respondents have a positive experience while witnessing the benefits of biohacking practices, the more they will be willing to reproduce the experience at work. The average score of both UX properties 'Pleasantness' and

‘Usefulness’ is close to 0,38 on the semantic scale. Compared to the other UX properties, these two are encouraging and tend towards an intention to adopt. Overall, positive experiences are more reported than negative ones which are justified by a lack of results (it didn’t work). Besides, respondents identified similar benefits and drawbacks of biohacking regrouped within the self-experimentation table in the literature review. However, respondents are more concerned about the possible side effects of an extreme following of the biohacking movement. In fact, some respondents are worried about a certain dependency that can be born from over-control, overdoing, or over-tracking. Therefore, after responses analysis, the author thinks biohacking practices at work has a potential of adoption if it doesn’t push too far workers to their personal limits and let them a freedom of choice.

Furthermore, the last minor research question is the open door to answer the main research question. Indeed, the author created a biohacking at work experience to determine factors impacting people’s adoption of biohacking within the workplace which are at the end the UX properties from the Research Framework of this study. Globally, all UX properties obtained a score between 0,32 and 0,57 showing that respondents are positive towards biohacking practices at work. Results show the more satisfying the biohacking at work experience is, the higher the degree of people’s adoption will be.

Finally, given that the three minor research questions would have been fully answered, the main one can be tackled. According to the collected data, the degree of people’s adoption and intention to adopt about applying biohacking at work is high. Indeed, the three dimensions composing the intention to adopt ‘Convincingness’, ‘Willingness’, and ‘Readiness’ have an average score of 0,62 on the semantic scale from -1 to 1. This score is encouraging but not incredibly high for several reasons communicated within the survey. On the one side, most of the respondents are curious to try out, enthusiasts about being more efficient and productive in task achievements but also seeking for increasing their well-being at work. Biohacking amateurs among respondents already witness positive outcomes so they are ready to recommend it to their colleagues. On the other side, some respondents think not all biohacking practices can be implemented at work, such as doing a power nap. They don’t feel ready yet because they are not familiar enough

with biohacking. Some of the surveyed people think biohacking is not for everyone which is felt a truth for the author because biohacking is related to the body and mind. Nature makes each body and mind work differently and each human experience different reactions. Therefore, in the working context, a firm can promote biohacking practices by encouraging a change in behaviour - without forcing employees to adhere - that starts with the employer's effort by investing in the office arrangement with ergonomics working environments which are employee's friendly, increasing well-being and performance.

6.3 Future Research

Future research should first of all target a bigger sample to do a statistical analysis that would tentatively validate the biohacking at work adoption model. Based on UX properties validated by Topolewski et al. (2019), the research framework of this study has all the elements to serve as the basis for a future empirical study based exclusively on quantitative data collection. In this case, it will be possible to generalizability draw conclusions for all workers.

Then, it would be interesting for the future to go deeper into the business potential of biohacking at work. In fact, the study was able to identify the potential of adoption for biohacking practices at work, but the economic benefits for a firm to implement biohacking practices within the working environment are beyond the scope of this study. The author showed in the literature review firms taking take of employees' well-being have a higher stock performance appreciation than other companies. Therefore, future research would focus on a method to quantify the positive outcomes for an enterprise to implement biohacking practices within the workplace.

Finally, the author would have liked to create a biohacking at work model intended for companies in order to help them to set the frame of such practices and ergonomics design of the workplace. Future research could rely on the holistic view of biohacking at work of this study, adapt practices to firms (e.g. working environment arrangement for allowing workers to take power naps), and test the potential degree of firms' adoption by an appropriate adoption model close to the one of this study.

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Appendices

Appendix 1. Questions of the Survey (N=31)

Q1. Can you define in your own words what BIOHACKING is for you? (if you don't know what biohacking is, go to the question 7)

Q2. Can you list all the key factors or topics you know that are related to Biohacking? (bullet points)

Q3. How do you perceive yourself in the world of the biohackers? (Not biohacker / Mostly not biohacker / Almost biohacker / Mostly biohacker / Biohacker)

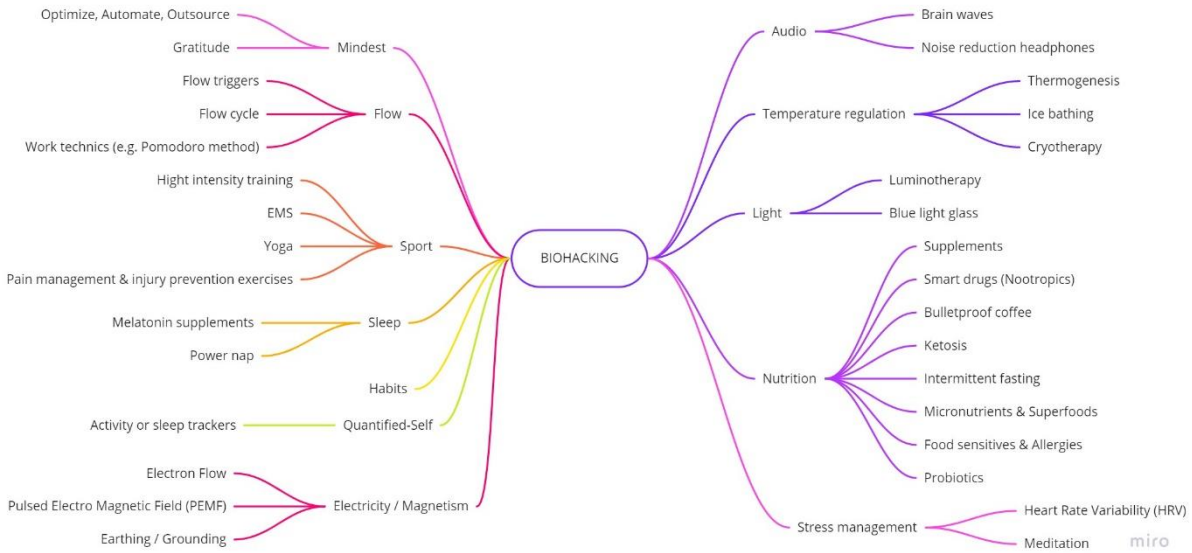
Q4. How interested are you about biohacking? (Not interested / Mostly not interested / Almost interested / Mostly interested / Interested)

Q4 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q5. How difficult is to recognize some actions or habits of your daily life are actually biohacks (linked to the concept of biohacking)? (Easy / Mostly Easy / Almost difficult / Mostly Difficult / Difficult)

Q5 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q6. How often are you associating a healthy action/habit with the biohacking concept? (Never / Rarely / Sometimes / Often / Always)



Q7. After having a look at this diagram, how different are your key factors described in the 2nd question of this survey? (Different / Mostly different / Almost identical / Mostly identical / Identical)

Q7 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q8. What is your opinion about this diagram? Does it regroup all the sub-categories of biohacking according to you? Anything missing?

Q9. Among all the sub-categories of this diagram, what is your personal level of implementation? (Never / Rarely / Sometimes / Often / Usually / Always)

Q10. Can you recall and share a POSITIVE experience about the impact of one of these sub-categories? ex: Light --> Luminotherapy lamp --> since I have it in the office, I feel more energized and alert.

Q11. Can you recall and share a NEGATIVE experience about the impact of one of these sub-categories? ex: Stress management --> Meditation --> I already tried but I didn't like it because I couldn't concentrate enough during the session and I felt tired after.

Q12. In general, define what biohacking benefits are important for you and why?

Q13. In general, what are biohacking drawbacks that you are aware of?

Q14. How convinced are you about the benefits of applying Biohacking practices at work? (Unconvinced / Mostly unconvinced / Almost convinced / Mostly convinced / Convinced)

Q14 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q15. What would be your level of willingness to apply Biohacking practices at work? (Unwilling / Mostly unwilling / Almost willing / Mostly willing / Willing)

Q15 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q16. How much would you recommend biohacking practices to your colleagues at work? (Not recommend / Rather not recommend / Perhaps recommend / Rather recommend / Recommend)

Q16 bis. Can you explain in a few words what are your motivation(s)/reason(s) that justify your rating?

Q17. What is your gender? (Men / Women)

Q18. How old are you? (18-25 / 26-30 / 31-45 / 46 or more)

Q19. Where do you come from? (country of origin)

Q20. What is the name of the company you are working for?

Q21. What is the sector of activity?

Q22. In which department are you working within the company?

Q23. How long are you working here? (less than 6 months / 6-12 months / more than 1 year / since the firm's creation (or employed some months later))

Appendix 2. Collected data from question 9 (survey)

	Never	Rarely	Sometimes	Often	Usually	Always
Sport	1	1	3	4	6	7
Sleep	2	2	1	4	9	4
Nutrition	1	3	3	2	5	8
Stress management	2	2	4	7	5	2
Habits	3	2	3	3	6	5
Mindset	2	3	4	3	8	2
Light	3	3	4	6	3	3
Flow	4	5	4	7	1	1
Temperature regulation	5	4	8	1	3	1
Audio	3	8	2	4	5	0
Quantified self (self-tracking)	7	6	1	3	2	3
Electricity/Magnetism	17	3	1	0	1	0