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PRACTICAL AND ETHICAL ISSUES OF PERSISTENT BEHAVIORAL AND NEUROPHYSIOLOGICAL MONITORIZATION FOR HUMAN PERFORMANCE OPTIMIZATION

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Abstract: *While not a new concept, human performance optimization (HPO) was virtually reorchestrated in the last decades by the rapid advancements in neurosciences, artificial intelligence, human-machine/computer interfaces, human medicine and microelectronics. Widespread acceptance and implementation of this concept especially at the university level and in specialized professions, both in civilian and military environments, raised technical and ethical questions and dilemmas. For example, persistent performances monitorization is an essential tool for recruitment, selection and optimization process that requires an extensive physiological, neurophysiological, emotional status and behavioral data collection. Multiple methods of data gathering can be employed – from direct (contact), limited in time and informed techniques controlled by the subject to non-contact, anonymous and indirect methods, for long periods of time, sometimes involving other subjects. The technical capabilities are rapidly expanding and are already allowing the anonime surveillance of large number of persons in situ (during normal routine, in public and even private spaces). The same problem is commune in digital medicine (for example, in behavioral digital phenotyping) and several initiatives are in progress, their scope being limited in particular by ethical and legislative issues and less by technical problems. In our paper we discuss the particular topic of performances monitorization from the perspective of several researches, from scientific literature and our own scenarios, in the field of human performance optimization. A comparative discussion based on the presentation and analysis of several systems and configurations used in our own research will allow us to provide an answer to the question "Are the pragmatic benefits of persistent performance monitorization outweighs the moral, ethical and security concerns for military professions?".*

Keywords*: human perforance optimization; human factor; persistent monitoring; neuroaugmentation; ethics*

1. INTRODUCTION

In the post-bipolar period, technological and social progress, as well as the prospect of accelerated development of artificial intelligence, generate strong pressure on human resources. In the military and intelligence field, an integrative vision of the role of the human factor, combining the permanent need for improvement, the impact of the technological environment and the new forms of conflict manifestation, has developed since the first decade of the 21st century.

Technical and scientific progress in the field of national security has forced the reconceptualization of human performance, defined as "the capacity of the individual as a unitary and biological entity to adapt to special conditions that exceed the functional limits for which man is conditioned ontologically and genetically". Exceeding parameters may be adverse (extreme environmental conditions, high stress, etc.) or intentional (performance gains, physiological or mental activities, etc.)

This vision represents both a new chapter in which the human factor is adapted to national security requirements and a prospective approach that takes into account the estimates of the role and technology of the 2050s. The events involving the United States military forces in recent decades, such as the conflicts in Afghanistan, Iraq, Syria, the global war on terror, have helped to validate the concept and accelerate research into the optimization of the human factor.

The concept of human performance involves measurements and comparative studies of the functional parameters that define the state of the individual or the collectivity investigated at a given moment and the evolution over time. This aspect presents a number of peculiarities in the field of human performance for national security, such as

the need to identify indicators that can characterize neurocognitive and emotional functions in dynamics, rapid and /or in-depth interpretation grids and the possibility of continuous monitoring, even in rest periods, training, simulation of the missions and post-action/recovery. These requirements include the need to secure data transfers, especially during missions, confidentiality of the personal biophysical data, judicious and impartial management of medical information, anonymization of data without the possibility of reconstruction or theft of the biometric fingerprint, etc.

The identification of descriptive functional parameters (both quantitative and qualitative), that are able to carry out an adequate assessment of the neurocognitive and emotional performance, is still a challenge for neuroscientists. Current solutions use a range of biophysical indicators, including neurophysiological parameters, acquired in real-time through non-invasive sensor networks, dermally (wet or dry) or contactless, and transmitted via tactical kits (smartphone, tablet) to a command center where raw information is automatically processed in real time based on specialized algorithms and interpreted by the mission medical officer.

During the last decade, superior cognitive functions and complex behaviors are monitored using advanced systems that are collecting digital indicators (the activity of a person in the virtual environment, regardless of the access method, including how to interact with the interface and peripherals) or by automatically monitoring and interpreting behavior in photo, video, audio, and other formats.

These approaches are derived from precision and personalized medicine initiatives, which represent the framework for the development of concepts such as digital behavioral phenotyping, remote behavioral monitoring and development of non-invasive mobile neurotechnologies (eg brain-computer or human-machine interfaces). These methods are more effective for the long-term monitoring required to establish a baseline activity level and algorithmic identification of behavioral anomalies or performance abnormalities.

In the course of two separate experiments, we used different monitoring strategies and devices that allowed us to evaluate to what extent persistent monitoring of functional parameters is useful in devising strategies for optimizing human performance. We have independently assessed to what extent persistent monitoring has the capacity to disclose personal issues, individual intentions, or to be a way of identifying a person where anonymity is required or solicited.

2. ETHICAL ISSUES

A controversial dimension of the concept of human performance optimization refers to the ethical issues that arise from the possible widespread application or the efficiency of the process. The idea of human performance optimization (or HPO) itself is questioned, but also the reasons (potential developers and users, public perception and opinion), the means used and its consequences are also a matter of debate. Debates on this issue is addressing to different topics, highlighting the challenge of rapid development in the research to improve human performance and the convergence of advanced technology.

One of the most debatable issues are the institutions that will regulate and influence technologies designed to improve human performance at a national and international level, the legal ways of approach and the type of political control that will be responsible for the development of prospective developments.

Unlike other similar practices operational neuroscience is not recognized and regulated in an international treaty, which leads some researchers to say that all five approaches (prohibition, permitting, encouragement, or laissez-faire) are potentially relevant. There is a difficulty in undertaking complex HPO studies which involve the practice of exposing healthy people to potentially detrimental procedures and also publish articles in top scientific publications due to ambiguous status, lack of consensus or the existence of specifically authorized organizations. Changing the design of clinical trials so that the control group can be used in neuroscientific studies is a practice at the limit of ethics and is difficult to validate as a current methodology (Farah *et al.*, 2004).

Healthy volunteer studies should be well defined and exclude exposure to significant medical risks (establishing therapeutic and health-related limits). Currently, most authors believe that regulations should be made by state authorities, and then be developed at the international level, given the potential social, medical and security implications - according to Robert Dingwall, 'the state has an obligation to ensure that inequalities already existent will not be aggravated and there will be no more harm by validating inefficient, unnecessary or dangerous technologies.'

It can not be ignored that the attitude of public opinion is changing rapidly, with a growing degree of enthusiasm and acceptance in the techno-progressive environments in the vanguard of the liberal society based on knowledge (young people from major cities, Silicon Valley, university cities, corporatist, etc.) or, on the contrary, rejection by traditionalists and conservatives.

Arguments for the development and use of human performance optimization bring into discussion concepts such as virtue, cognitive freedom and cognitive autonomy, utilitarianism, the acquisition of new superior capabilities, issues considered fundamental for the ethical use of HPO.

Thus, the use of performance optimization is justifiable from the point of view of utilitarian morality (according to which an action is moral if it brings an improvement for as many people as possible, in the absence of other prejudices) and the principle of autonomy (a right of the person, expression of individual liberty), but condemnable from many other points of view (social injustice, security risks, unpredictable consequences).

Another aspect is the management of the medical resources and the correct distribution of medical services, given that the improvement in performance requires a highly qualified human resource and medical equipment, a mechanism that can help reduce access to health services for disadvantaged socio-economic individuals, increasing the social and cognitive gap or may increase the cost of complex medical services. As a conclusion, most authors find the need to regulate issues related to HPO and related emerging technologies, in the context of a competitive (social, economic, political, military) race globally, which tends to increase inequalities between different social categories, professional or ethnic.

For national security institutions, resource management is essential, given the unpredictability of the security environment, so benefits and risk control must justify the investment in HPO technology. In turn, these institutions can be involved in building a legal basis for advanced technologies in issues related to combating high-risk drug trafficking, the proliferation of dual-use technologies, illegal services to optimize the human performance of criminal or terrorist organizations, discrimination, social injustice, stigmatization, banning political trends that harm human dignity, etc. In the context of a lack of regulation, the risks generated by the research in the field of human performance optimization are far from being defined and known, therefore a prospective approach is necessary.

Another aspect is the risk of proliferation of dual-use technologies, human performance optimization technologies making use of or using a range of high-tech dual, civil and military dual-use technologies such as artificial intelligence, neuro-biometry, brain-computer interfaces, advanced robotics, nanotechnologies, genetic engineering. Even if these technologies are strictly controlled and regulated, their convergence can generate products with potential military applications.

The approach is quite similar to that encountered in the case of autonomous artificial intelligence, considered to be another dual-use technology generating major security risks, difficult to predict. The preventive argument, so invoked in relation to emerging technologies over the last half-century, stipulates that although the current development of neuroaugmentation does not pose a serious threat, the next generations of neuroaugmentative technologies will generate major security risks, difficult to anticipate and counteract, so the overregulation or prohibition of military-purpose research should be a priority of science policy.

Invoking the similarity with artificial intelligence, there is a growing concern that augmented individuals will have both an increased interest in improving these methods, as well as cognitive resources and other means to self-perform faster than the rest of the unrelated individuals. The fusion of human and artificial intelligence through advanced neurotechnologies is theoretically possible, but it also does not offer predictability in terms of finality and morality, especially in the military field (Stibel, 2016).

Affective modulation is another area of interest for national security services, offering the possibility to significantly influence individual and collective behavior, memories, the way of perception and interpretation of reality, social relations, crowd control, decision-making, persuasion, and dissuasion, etc. Even though it is not one of the direct aims of HPO and especially neuroaugmentation, however, the technology, working methods, and expertise have major similarities. A series of researches conducted in military institutions aims at improving current techniques of emotional manipulation, including developing advanced elements of affective computing (Dugan, 2015).

Neuropsychological aggression is increasingly a component of new forms of conflict, such as informational conflict or hybrid warfare, which also has the effect of degrading the cognitive and emotional capacities of the population subjected to

cyber-informational aggression. Research in the field of neuroscience has made it possible to achieve a high degree of refinement of psychological operations or marketing campaigns, being affected by the decisional capacity through simultaneous cybernetic operations (Barna & Dugan, 2015).

A feature of future conflicts will be the use of "Enhanced Human Operations", centered on the use of man-machine concept (the centaur approach), advanced robotics, exoskeletons, directed-energy weapons, augmented soldiers. There is fear that some hostile countries are involved in the development of military augmentation means to provide an asymmetric advantage, benefiting from the lack of legal regulation, encouragement by the authoritarian political factor and use in proxy conflicts.

Probably the most important legal aspect of optimizing human performance is the conceptualization and, in particular, setting boundaries and interface areas with similar practices. Although there is a consensus on the finality of the optimization process and, to a large extent, on the methods that can be used, a number of issues remain unclear and require an ethical and legal disambiguation. The process is not a purely academic one, with multiple interests in the commercial, social and political area.

It is to be expected that in the coming decade, as new efficient means of cognitive augmentation will be validated and operationalized, the debates in the legislative and political spheres will become more and more intense, tensions and precursor elements of these conflicts being identifiable at present.

The seemingly disproportionate interest in ethics in relation to medical and societal risks is largely due to some of the historical aspects associated with human performance research. During the Cold War, human performance research has become more extensive, diversified and sophisticated, with particular concern for individual and collective manipulation and behavioral modeling, neuropsychological optimization, methods of protection, interrogation techniques, remote information attacks, social engineering techniques, etc.

Although it is not possible to carry out a detailed evaluation of these experimental programs, based on disclosures and declassified documents, we can say that there have been numerous violations of codes of ethics and human rights. In view of this approach, ethical discussions aim to contribute to the understanding and clarification of HPO concept, contributing to the creation of a legislative foundation aimed at preventing the health consequences, the dignity of the person and facilitating the development of the positive aspects of the field (Szafranski, 1994).

For national security organizations, the concept is undoubted of interest, especially in its operational part, as an asymmetric methodology of obtaining supremacy in the infosphere. There is so far a sufficient amount of research and practice to justify involvement in the development and use of these techniques for the staff in national security institutions, but also to study a number of related themes (targeted neuropsychological deterioration, personal neuroprotection, implications of political nature).

3. EXPERIMENTAL RESEARCH

Project CONCEPT ONE (short for "Computer aided sistem for opto-neural performance evaluation and optimization"), consisted of an evaluation mock-up, which represents the first generation of a human-computer interface that is meant to assess neurovisual performances. We used the following devices: an eye tracking device (The Eye Tribe – which calculates the eye gazing, pupillometry and the movements of the mouse), a 14 channel EEG headset (EMOTIV Epoc +), a multi-frame camera (330/500 frame/sec – which captures facial micro-expressions and micro-saccades), a galvanic skin response evaluation sensor, an automated analysis software of facial emotional expressions from video (7 basic emotions), a pulse meter.

We used multiple pre-processing, processing and visualization programs (LabVIEW, Matlab, NeuroSim, BioExplorer, BioPack Student, NeuroGuide etc.), due to very large differences in between the softwares pertaining to each recording channel; this also led to the carrying out of an offline analysis of data. Two main applications were implemented: an efficiency testing and evaluation of a neuroaugmentation program for pre-flight security screening officers and an evaluation of neurophysiological and visual reactions following exposure to (photo, video, audio) Russian propagandistic materials. Although technically speaking one may conclude that the two research endeavors have many features in common, they are in fact separate and are proof of the human-computer interface capacities and versatility.

Another application targeted evaluation of neurovisual behavior while taking intelligence tests

during an HR recruitment and evaluation type scenario. Starting from large-scale utilization of intelligence tests during recruitment processes, we evaluated neurovisual performances during the application of test batteries (comprised of Raven matrices, mental rotation tests, spatial intelligence tests, chromatic discrimination tests and pareidolia tests). The objectivation of visual search patterns yielded the most relevant information regarding strategies for solving intelligence tests.

The pilot-research aimed at evaluating neurovisual behavior of a cybersecurity expert was inspired by an experiment carried out by Sandia Labs in 2015, and published in an article entitled "Measuring Human Performance within Computer Security Incident Response Teams". In lack of a large number of IT experts that could form a relevant group of subjects, we focused instead on implementing a number of situational scenarios as designed by a cybersecurity expert. Interesting results were obtained in one scenario in which two IT experts had to simultaneously react to a critical security breach (although each of them used its own computer, coordination and cooperation between the two experts constituted significant elements of the scenario).

The research of cognitive optimization was aimed at facilitating fast learning and identification of those factors involved in national security personnel cognitive performances augmentation and degradation. The research of neurophysiological and emotional reactions following exposure to propaganda allowed us to produce comparative analyses in between different groups of subjects (selected by age, gender, command of the Russian language etc.) and to evaluate their involuntary reactions.

Project "**Integrated System for Support and Management of Interventions in Crisis Situations**" (acronym SENSOR CENTRIC). The project produced a series of solutions for the following challenges facing a set of actions which are carried out in a multi-agency context in order to manage intervations in crisis situations: 1) increasing the efficiency of information flows (EFUXION), 2) optimization of human factor performance (OPTIMUM) and 3) tactical awareness for the decisional architecture (CARDINAL).

The Human Factor Performance Optimization component (OPTIMUM) represented an application of the human performance optimization concept that was implemented by the US army and NATO, with focus on the neuroaugmentation component. The real-time monitoring of neurophysiological parameters in resting periods, during drills or in tactical and post-response operations aimed at producing a precision digital medicine type approach in operational conditions, which in effect meant a detailed understanding of the capacity for physical and intellectual effort, medical vulnerabilities and maximal performances within the limits of safety. The approach enables monitoring of drill and optimization strategies, thus generating competitive advantage by means of human factor efficiency, risk conditions predictibility, flexibility and resilience. The process is coordinated by the medical officer whose role is to evaluate the general medical and operational state of the personnel, to inform and advise the head of mission, to offer first aid help in usual situations or in case of incidents/emergency, and to formulate recovery and performance optimization strategies.

Within the OPTIMUM component, a wearable biosensors subsystem was developed at conceptual level, that was aimed at distance monitoring of physiological parameters of intervention teams, and composed of a biosensors vest, an external environment sensor, an electroencephalography helmet for evaluation of cerebral electrical activity and an optional eye tracking and ego-centric vision (first person vision by using a wearable camera) system.

The biosensors vest is based on a specialized comercial product (for the military and/or athlets) that was tested in the US and in the European Union. It is adapted for long-term wear (> 24 h), intensive effort and prolonged rest (including sleep), and comes in multiple designs according to dimensions (for adults, children), gender and thermal comfort (for summer, winter or extreme weather conditions). The device is light, ergonomic, resistant, can be reused, and can be subjected to customization according to individual needs. In addition, in combination with a protective garment (e.g. neoprene swimsuit), it can also be used by divers or parachute jumpers. Its sensors enable recording of the following biological and nonbiological direct or derived indicators:

1. electrical activity of the heart by means of a single channel electrocardiogram (ECG): heart rate, linear and nonlinear analysis of the cardiac rhythm and ECG morphological aspects;
2. respiratory activity by means of a two-channel sensor – respiratory frequency, spirometric indices –, and acceleration by means of a three-channel sensor – activity type, pedometer, cadence,

active and resting periods, distance calculator, energy expenditure and caloric consumption;

3. activity during sleep: automatic detection of sleep and wake-up reaction, hypnogram, body position changes and sleep efficiency;

4. position and field localization by means of a GPS sensor.

The sensors can be modified, supplimented, reconfigured, redistributed and calibrated. This flexibility enables further adaptations according to the profile of the monitored activity or mission. In case of an incident, the biosensor system would perform the function of a medical monitor, that also enables the uploading of the data flow directly into the national telemedicine system. The data flow transmissions would be carried out on a real time basis both by means of the device and by an independent and supplemental transmission system, thus ensuring data redundancy and security as well as resistance to jamming of wireless transmisions.

The mobile electroencephalography helmet with dry electrodes for monitoring of the electrical activity of the brain ensures real time recordings in tactical conditions, without supressing hearing. The product is comercial, modular, resistant, ergonomic, expandable and filters mechanical and electrical artefacts. Several configurations are possible (8, 16, 24, 32, 64 electrodes), to which other biosensors can also be attached. The device can be used in resting periods, during drills and simulations, for personnel evaluation and increase of performance, but also to a certain extent in real life situations.

Simultaneous recordings of the cerebral electrical activity of the members of a team offers data on group synchronization, comparable reactions to stress stimuli, degree of attention and concentration, physical and psychological stress resistance etc. Simultaneous integration of physiological information sent by the vest-embedded biosensors together with the results of the electroencephalography offers a much more detailed insight on the individual and collective performances and on their influencing factors.

The eye tracking and ego-centric vision system enables video recordings of the visual field of the user and reconstruction of the visual dynamics. It is useful for optimization of training and simulation strategies as well as for evaluation processes of staff that works with monitors, maps etc. (in general, any visual information that is displayed on short distance bidimensional screens). Visual information integration with that produced by the EEG enables a multidimensional characterization of neurocognitive performances of high-level personnel.

One drawback is that although the information obtained by means of the eye tracking device can be used immediately, in-depth evaluation can last for a longer period of time and can be semi-automated. Integration of information produced by the EEG and that obtained from the rest of the biosensors is yet another time-consuming process, which results in nearly-real time sending of information. The problem can be overcome by application of big data solutions or developing of early warning alarms that signal significant performance variations etc.

5. CONCLUSIONS

One of the findings of the experimental research presented is that by knowing in detail (some) neurophysiological or psychological peculiarities, behavioral patterns, relational configurations, possible health problems, etc. offers the decision maker a profound insight into the capabilities and vulnerabilities of a person of interest. This oversight can address both adverse and high-value human targets. Similarly, the selection and recruitment process can be improved by persistent, noncontact (anonymous) monitoring of neurocognitive performance and affective status for a prolonged period, in normal work conditions. Digital behavioral phenotyping, along with (mobile) methods to monitor neurophysiological parameters in simulated and real conditions, provides a more detailed picture of the ability and potential of a candidate's aptitude.

The development of countermeasures for specific demands within the military professions is another direction of capitalizing on the concept of human performance optimization. This pragmatic approach, encountered in special professions (astronauts, deep-sea divers, climbers, extreme sportsmen, arctic explorers) can generate innovative solutions capable of revolutionizing weapon systems or reaching a maximum human performance threshold (used in operations with augmented personnel - enhanced human operations).

A more general approach allows the development of countermeasures in usual situations commonly encountered in military professions (chronic deprivation of sleep or a longer time, reduction in operative performance during prolonged activities, loss of combat capacity due to physical fatigue, etc.).

The concept of human performance optimization is also a platform for cutting-edge research into the field of neurosciences, applied neurotechnologies, artificial intelligence, and related branches. Accelerated technological development, particularly in the field of neuroscience and information and communication technology, has increased the probability of materializing "technological surprises" based on niche strips, generating asymmetries in the information market. Branches of the mentioned domains are vast and have a great commercial and military potential.

As a final remark, we consider that a worrying expectation is also the social pressure to use performance optimization methods in response to existing demands in an increasingly competitive and motivated society. In reality, this demand is fueling a vicious circle, augmentation causing even greater pressure on the need for social and professional success, as well as generating a new cycle of optimization and augmentation, usually more radical and risky.

In this context, we consider that the unauthorized and non-supervised use of HPO techniques by employees of national security institutions represents a risk, given the extremely competitive environment during the training period and the restrictive requirements in the operational environment. We underline the importance of ethical research and the legislative impact when adopting and using the concept of human performance optimization.

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