CyberGenomics

Subjects: Genetics & Heredity | Computer Science, Interdisciplinary Applications | Psychology
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Cybersecurity (CS) field is a complex discipline with multiple layers. We deconstruct the CS specialist as a material (naturally/ genetically determined) and non-material (psychologically determined) entity. This entity is mapped to CS competences required to conduct everyday tasks where psychological factors are also present (e.g. stress). All the structural prerequisites for the development and functioning of the psyche are genetically coded and controlled. Behavior genetics addresses the interdisciplinary effort to establish causal links between genomic loci and human behavioral traits and neural mechanisms. Almost every human behavioral trait is a result of many genome variants in action altogether with environmental factors. Cybergenomics focuses on contextualizing the behavior genetics aspects in the application of cybersecurity.

Keywords: cybersecurity ; human factor ; stress genomics ; behavior genetics ; complex traits

1. Introduction

CS positions are considered stressful due to the complexity of the domain and the social impact it can have in cases of failure. The defense must be timely, as errors might cause severe effects. Attack models and vectors are becoming more advanced due to the development of technologies. Many soft skills lead to complex human behavior. One of the soft social skills shaping factors might be genetic factors. Almost every human behavioral trait is a result of many genome variants in action altogether with environmental factors. The development of the technologies not only reduced the cost of genomic data generation but also introduced many approaches to studying the interconnectedness of phenome-wide and genome-wide coherence. A big leap was genome-wide association studies (GWAS) that identified hundreds of genome variants related to particular behavioral traits. Recent technological advancements bring challenging possibilities in the applications of human genetics and CS. The integration of genomic approaches into the analysis of social/behavioral traits might deepen the understanding of biology for human behaviors. Furthermore, risks related to the behavior of the person may be determined and considered in the CS field. A CS specialist who understands the risks of his behavior can better adapt to adverse environmental conditions and cope with risk factors through well-rehearsed techniques.

2. Genomic Factors

In general, the genetic architecture of a phenotype refers to an entire complement of underlying genetic factors, including their number, variant frequencies, and effect sizes of contributing variants. Today, technology allows for the genotyping of individuals to extract sets of genomic variation. However, common DNA variation adds only a small effect to the phenotype, and many variants are contributing. Thus, there is a need to identify lots of variants. Knowledge of the DNA variants that an individual carries can only predict the genetic value of the individual for a trait. To get the complete picture of a particular trait, a consideration of the environment is necessary.

Human and model organisms' (e.g., monkeys, dogs, rodents, and other) studies are the two main types of methodologies to investigate behavioral traits.

To determine whether the trait is inherited, it must run in families, and when the significant familial recurrence ratio is achieved; it can be concluded that the disorder is familial. To evaluate heritability [1], i.e., what fraction of a trait variation depends on genetic factors, human studies mainly involve twin pairs or sibling analysis strategies. The point is that we can relatively distinguish the environmental factors from genetic factors as twins or siblings typically experience similar environments while growing up [2][3]. Furthermore, siblings are concordant for ancestry and display negligible differences in population structure [4]. Heritability ranges from zero when there is no contribution of genetic variants to the phenotypic variation to 100% when phenotypic variation entirely depends on genetic variation (i.e., monogenic).

Establishing that a genome variant, gene, or gene set is associated with a disorder, or a trait of interest is only the first step in answering the question of how specific genes contribute to the disorder or the particular trait (e.g., behavioral aspect related to a skill/characteristic which is desired/undesired for CS specialist). A wide range of molecular, cellular, and clinical research studies may be needed to characterize the mechanisms involved. These include studies of gene expression, animal and cellular models in which genes may be experimentally altered to study functional effects, and clinical neuroscience studies (e.g., neuroimaging and neurophysiology) examining the effect of genetic variation on brain structure and function [5]. Once the genetic factors of a trait are mapped, then we can proceed with the models for trait prognosis, or if it is a disease/condition, estimate the risk. There are several established methods on how to predict traits, and this field is quickly evolving.

Modern behavior genetics studies face ethical concerns relating to the medicalization of behavior traits, mistreatment, and abuse of information for insurance or employment, social aspects of information misuse such as public discrimination, impact on law and judgment, and the risk of modern eugenics. Eugenics was rather a misunderstanding of inheritance, thinking that a single gene can account for a complex behavioral trait. Evaluation of ethically concerning aspects and determination of measures have to be taken in order to tackle ethics-related risk management.

3. Psychological Factors

Recent research has shown that genetic heritability of personality is calculated to be 0.40, but this varies depending on which personality inventory is used and which personality factors are measured. It was shown that there are discrepancies in genetic explanations for personality factors and that new techniques, i.e., next-generation sequencing, can help better understand the genetic contribution to personality factors.

The role of stressful environments and the physiology of stress response systems have been most closely linked to depression, anxiety, and traumatic stress disorders. How do we identify those individuals who are more susceptible to stress? This knowledge is important for an individual when choosing a profession or place of work, as well as for the institution hiring a specialist. For the more susceptible ones, stressful working conditions such as flight control or CS might be too difficult to cope with. Studies are showing that individuals might differ substantially according to how they respond to similar experiences. It has been demonstrated that environmental sensitivity depends equally on genetic factors as well as on environmental factors and that there are overlaps between personality traits of neuroticism and extraversion [6]. Also, as an example, it has been shown that the evaluation of the glucocorticoid receptor gene variant could help to identify children differentially susceptible to stress and intervention to overcome adverse negative environmental effects. Thus, information on the genetic background could be valuable if we would like to influence certain behavior or a good indicator of whether we should invest money and time in that person [7].

4. Concluding Remarks

Multicomplexity/multifactoriality of the discussed research field—the behavioral genetics of the aspects of the cybersecurity specialists' activities is the main challenge in identifying the wide combination of most possible factors. The ever-increasing number of GWAS hits harness the power of molecular genetics to identify specific genes responsible for genetic influence on reacting to environmental triggers, such as stress. Future research findings will be utilized for the analytics of the prediction scores. As well the delineation of specific combinations of genomic factors and environmental factors (or construct of gene-gene and gene-environment landscape plot/map) will suggest the best calculation methods and attempt for ranging those prediction scores. The work can be extended in several directions. Pilot studies should be executed to evaluate exercise implementation and collect quantitative data for further research. Behavioral Neural Networks should also be addressed to identify the risks detection process and the needs for behavioral references. Risk assessment strategies with more precise parameter settings should be built with additional risks in mind. Evaluation of ethically concerning aspects and determination of measures have to be taken in order to tackle ethics-related risk management.

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