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Will the biopsychosocial model of medicine survive in the age of artificial intelligence and machine learning?*

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Abstract

Background: the biomedical model of medicine was replaced by the biopsychosocial model in order to better accommodate psychological and social aspects of illness. The introduction of machine learning techniques provides the perspective of truly personalized medicine. This poses new challenges to our medical model.
Aim: to explore the implications of personalized medicine for the biopsychosocial model.
Methods: scholarly reflection
Results: The ability of machine learning technology to integrate a wide diversity of data makes it possible to develop predictive models for presentation, course and treatment response in individual patients. Such models are based on individual risk factors and protective factors that may have diverging influences in different individuals. In a medical model adjusted to accommodate the possibilities of personalized medicine, it should be possible to highlight the importance and impact of each single factor in each individual patient. At present, the biopsychosocial model is not well prepared for this.
When adopting machine learning technology in clinical practice, new skills and expertise will be required from physicians. They should be able to weigh and explain algorithms supported decisions to their patients. Moreover, new research should be designed in such a way that data will be suited for machine learning and can be integrated with existing databases in order to increase their size and scope.
Conclusion: Currently, the biopsychosocial model is not well prepared to accommodate the possibilities of personalized medicine. Adaptations are needed to deal with the highly individual aspects of the patient's disease.

Key words : biopsychosocial model, psychosomatic, artificial intelligence, machine learning, predictive model

Introduction

The biopsychosocial model is the leading model in modern medicine. The model was originally coined in 1977 by the American internist and psychiatrist George Engel out of dissatisfaction with the biomedical model. He considered this biomedical model, which was the predominant model at the time, reductionistic since it did not leave '*room in its framework for the social, psychological and behavioural dimensions of illness'.* In his opinion, medicine as well as psychiatry were in a crisis that derived '*from the basic fault of ….adherence to a model of disease that is no longer adequate for the scientific tasks and social responsibilities of either medicine or psychiatry*' (1). He formulated the need for a new medical model, which he called the biopsychosocial model.

In present times, the rapid developments and vast horizon of potential clinical applications of artificial intelligence and machine learning poses new challenges to our medical model. These technological developments prepare the way for truly personalized or 'precision' medicine, with diagnoses and treatment decisions made on the basis of individual patient's characteristics using individualized models to predict treatment response and disease course. Such a personalized approach will drastically change patient care as well as medical research (2). In this paper we argue that our biopsychosocial model is currently not well prepared to meet the requirements of personalized medicine, and that adaptations to the model are needed in order to provide a framework that is able to deal with this new approach.

History and benefits of the biopsychosocial model

Engel's biopsychosocial model was based on the 'general systems' theory' of Bertalanffy (3). The *'organism',* or patient, was described as organized in different hierarchical levels of systems, whereby larger and more complex systems take a higher position in the hierarchy than smaller and less complex systems (Figure 1). In this hierarchy, every system can be considered by itself, but also as a component of a higher system (1). As such, the patient is considered the highest level of the organic, or biological, hierarchy, but at the same time as the lowest level of the societal hierarchy.

Whereas this model may appear a largely theoretical construct, it was developed with the explicit intention of being a practical aid to clinical assessment and diagnosis. It was thought that by following a structured approach that routinely considered psychological and social aspects of disease in addition to the biomedical aspects, no potentially contributing factors would be overlooked. Illustrative examples applying this approach are given in Engel (1980) and Adler (2009) (4,5).

From a clinical perspective, the new awareness of the importance of psychological and social aspects of disease not only facilitated physicians in adopting a broader and more holistic approach to disease and its treatment, but also helped physicians to become more aware of the therapeutic potential of the doctor-patient relationship (6). From a research perspective, the new model provided the framework for a large body of psychosomatic research that delivered insight into the influence of mental symptoms and social circumstances on physical health and vice-versa. As a result, the importance of mood, anxiety, and stress, as well as economic circumstances and social support on physical health and disease became widely acknowledged, not only in research, but also in everyday clinical practice. This is reflected by the fact that psychosocial and psychological aspects are now routinely considered in clinical practice guidelines for chronic physical and psychiatric disorders.

Limitations of the biopsychosocial model

Although face-valid, Engels' approach has received criticism from both a clinical as well as a scientific perspective.

From a practical clinical perspective, the 'bed-side' application of the hierarchical systems approach turned out to be too elaborate for wide application in routine patient care. However, the biopsychosocial approach with the explicit mention of biological, psychological, and social aspects survived and laid the basis for the development of multi-axial systems for diagnosis and classification, such as the International Classification of Primary Care (ICPC), and the Diagnostic and Statistical Manual of Mental Disorders (DSM) (at least up until its 4th edition), that are still widely used in clinical practice today (7-8).

Although the biopsychosocial approach implies that all aspects, including biological, psychological and social aspects, that potentially contribute to the disease of a patient are considered, the approach does not inform us about the relation between these aspects and the disease: causal, contributing, coincidental or unrelated. Moreover, it does not highlight what the relevance of any specific risk or protective factor is in a *specific* patient.

It is well known that disease presentation and course, as well as on treatment response, may vary widely between individual patients and, apart from disease characteristics, strongly depends such factors as personality, coping skills, early life experiences as well as on highly personal events and circumstances (losing a loved one, financial adversities, etc) that are usually not considered in traditional research. If we do not know the impact of such psychological and social factors in a specific patient, the mere listing of these aspects on different diagnostic or classificational axes will not help us decide on an intervention or treatment plan.

One explanation for this shortcoming is the fact that almost all medical knowledge to date is based on *group* level studies. Practically all current study designs are focussed on observation or comparison of *groups.* Attempts to translate information derived from group level studies to the *individual patient's* needs is done by trying to identify a limited number of disease subtypes with a more specific presentation, course and treatment response, and subsequently assigning the patient to one of these subtypes. However, whereas this approach certainly has led to great advancements in medicine, it fails to explain the wide variability of disease course and treatment response between patients in most diseases, even within subtypes, and does not help us to select treatment that is likely to be the most effective in a specific individual patient. The biopsychosocial model as we currently use is thus not well suited to deal with the diverging and highly specific influences that the same predictor variable may have in different patients.

Emerging possibilities of artificial intelligence and machine learning

Machine learning is a subfield of artificial intelligence that focuses on the use of data and algorithms to imitate the way that humans learn. Especially with unsupervised machine learning techniques it becomes possible to identify hidden patterns in datasets, without a predefined hypothesis. Algorithms are used to analyse and cluster data in high volume datasets from a large variety of different sources and with widely differing structures and qualities. In fact, the more diverse the data, the more accurate predictions can be made (9). Hence, demographic data, disease-related clinical information, laboratory tests, imaging findings, genetic constellation and other data can all be combined and integrated with data on individual patients' physical and mental comorbidities and its treatment, past responses to treatment of the index disease, as well as past adverse or positive life experiences, social and economic circumstances, personality features, coping styles, lifestyle, perspectives on life, etcetera. The ability to deal with such magnitude and wide diversity of data makes machine learning techniques highly suitable to not only develop predictive models on a group level, but also on an individual level. By using a combination of supervised and unsupervised machine learning approaches it becomes possible to establish a diagnosis, estimate disease course and predict treatment outcome based on the integration of both generic and personal predictors, making the resulting prediction model highly individual. This opens the way for truly 'personalized medicine' or 'precision medicine' adapted to the individual patient.

Another way of personalizing diagnosis and treatment is by focussing on repetitive real life assessments in single individual patients. By using 'experience sampling' or 'ecological momentary assessments' the subjective experience of symptom severity in individual patients can be followed over time. Using such methods, a large body of data is collected within one individual patient, that enable analyzing the relation between symptoms among each other, between symptoms and context, as well as between symptoms and timing of medication (10). This may be helpful in personalizing a treatment plan.

Such an individualized approach will eventually make group-level approaches largely irrelevant. The identification of subtypes of patients with a specific disease to better predict prognosis becomes irrelevant if a *personalized* prognosis can be made for the *individual* patient. Likewise, the identification of markers for diagnosis or treatment response on group level becomes irrelevant if predictions can be made for *individual* patients. In a medical model that is adjusted to accommodate the possibilities of personalized medicine, it should be possible to highlight the importance and impact of each single variable, whether risk factor or protective factor, for predicting diagnosis, treatment response, and disease course in an individual patient.

Consequences and impact of machine learning and artificial intelligence

Personalized medicine will have great impact on clinical care, the doctor-patient relationship and research.

Predictive models for individual patients, as generated by machine learning techniques have several great advantages. They will not only lead to earlier and more reliable diagnosis, but also improve treatment. Instead of going through a uniform 'one size fits all' stepwise protocol of escalating treatment options, the model will identify the most effective and suitable treatment based on the patient's characteristics. This implies that certain steps in a multistep protocol may be skipped and patients receive adequate treatment faster. One of the disadvantages is that with this highly individualized approach based on complex technologies, the physician may lose oversight and a sense of control. Information will become increasingly complex and the physician has to rely more on decision aids based on techniques that he does not, and cannot understand anymore. In the new approach, not the disease, but the patient will be central. An intelligible *disease model* applied to a patient will be replaced by an unintelligible *patient model* for the disease. This requires a new definition of the relation between technique on one side and the experience and expertise of the physician on the other.

Dealing with these new technological possibilities requires that the physician searches for a new role and identity as doctor. One of the adaptations required for the physician role is that working knowledge of symptomatology, aetiology and treatment on group level becomes less relevant, but translating and explaining decisions made on the basis of algorithms or clinical decision aids based on machine learning to patients will become more important. This will require new skills and expertise. In addition, although the algorithms may be more accurate, they do not eliminate medical uncertainty and may even lead to inaccurate recommendations if relevant factors for individual patients, that are not included in the algorithm, are not taken into account (9). For these reasons clinicians must remain watchful. It will still be necessary to combine machine learning software with clinical expertise provided by the physician (11).

Preparing the way for personalized medicine

The biopsychosocial model did not discard the biomedical model, but rather extended it to accommodate psychological and social dimensions. This adaptation facilitated further developments and innovations in both patient care and research. Currently, due to developments in machine learning, we again run into the boundaries of our medical model. The biopsychosocial model needs a way to incorporate the highly personal aspects of diagnosis and treatment in the model. Such an updated model, that focuses on the individual, would facilitate research into personalized medicine as well as its application in clinical care. Large prospective datasets will still be needed, but they will not be used to learn about groups, but serve as a vehicle (‘data cloud’) to derive personalized predictions about diagnosis and treatment effects for individual patients. In addition, n=1 clinical assessments, e.g. with ecological momentary assessments, will gain importance (12).

New prospective studies should be designed in such a way that individualized predictive modelling will be facilitated, e.g. by incorporating more, and more diverse, personalized variables, such as life events and personal circumstances, etc. in order to allow ever more accurate individualized predictions. Moreover, frequent real life assessments may provide a better view on the individual patient’s burden of disease, symptom networks, and treatment response (12). Machine learning can deal with the magnitude of data that such an approach generates.

Individualized predictive modelling requires large databases. Databases should be harmonized across studies in order to be integrated and expanded. New studies should collect data in such a way that they will be suited for machine learning and can be integrated with cumulative databases.

Acceptability of machine learning algorithms needs to be enhanced for both patients and physicians. This can be done by prioritizing 'white box' machine learning techniques over black box machine learning. In 'black box' machine learning the classification algorithm remains “hidden” which preclude their interpretation, whereas in 'white box' machine learning the resulting algorithms can be expressed as a discrete mathematical expression, making the computation explicit and quantifying the influence of all predictors in the model (13). This does not mean that explaining the context of decisions to patients and physicians will become easy, but it is a first step towards our understanding of the algorithms and quantifying the contribution of specific individual predictors. Explaining algorithm-based decisions to patients will be a challenge that needs to be addressed before clinical implementation of personalized care can be successful (14). Salient ethical questions need to be addressed as well: to what extent do patients want to know what can be predicted about disease course or treatment response, or do they consider the additional, accurate knowledge about their near future an undesirable burden? While the focus on increasingly on personalization, it becomes all the more necessary to consider the patient's personal set of values on what they want to achieve or avoid in their lives. Shared decision making about treatment options will become more important. We should not lose sight of the person in moving towards personalized medicine.

Conclusion

The biomedical model was transformed into the biopsychosocial model in order to better accommodate psychological and social aspects of illness. The introduction of machine learning in clinical care brings with it the new perspective of personalized medicine. From this perspective, the biopsychosocial model as we know it could be considered reductionistic since, to paraphrase Engels,
it does not leave '*room in its framework for the highly personal and individual dimensions of illness'.* Here we argue to extend the model by creating a way to incorporate the highly individual aspects of diagnosis and treatment and their relevance for the individual patient. Even though the wide implementation of machine learning techniques in clinical practice may still seem far away, the developments are rapid and the implications far reaching. It is therefore not too early to start thinking about these implications in order to facilitate acceptance among patients, clinicians and researchers and to guide implementation of machine learning applications in clinical care and medical research. If we contemplate and anticipate these forthcoming changes, the biopsychosocial model of disease may develop into an holistic and integrated individual patient model for disease in time to facilitate effective implementation.

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Figure 1. The biopsychosocial modal as proposed by Engel, based on the general systems theory by L. von Bertalanffy (1977) (1, 3).