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Mathematical Models of Diagnostic Tactics in Psychiatry

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Diagnosis is final part of diagnostic procedure. However, the stages of diagnostic process remain unexplored. Classic diagnostic procedure consists of three stages: verification of symptoms, verification of syndromes, and verification of decease. However it is clear that there are other processes in the mind of a psychiatrist. Internationally accepted diagnostic criteria were adopted to unify of diagnostic nomenclature. All of them are based on the same principles: inclusion criteria, exclusion criteria, time of illness.

For more precise use of such diagnostic criteria diagnostic scales were built according to the same principle.

We base our approach in the supposition that different diagnostic parameters used in a given scale have different weight. This assumption is based on diagnostic practice: it allows a physician that possesses only one symptom to build the entire diagnostic chain. In some cases there can be the situation when the whole diagnostic process collapses and search of symptoms is conducted in reverse: from diagnosis to symptoms. In some cases such tactics can lead to diagnostic errors because in this situation the search is not for really existing symptoms but for symptoms that are necessary for diagnosis. As a result the latter get unreasonably large weights whereas existing symptoms are ignored.

The tactics described above make it possible to define the principal parameters of the process of diagnosis. We succeeded in showing that even where there are few patients the individual diagnostic patterns can be defined. These patterns vary from one psychiatrist to another and are revealed in different distributions of weights of diagnostic parameters.

Thus, we have to define a new measure that captures these patterns. In our terms they describe dynamics of changes of relative distributions of weights for different patients. The mirror problem will be to define a new variable that determines persistency of these patterns.

For simplification let's consider the situation when there are only two patients. In this case we can restate the problem in the following way: to what extent the relative distribution of weights of diagnostic parameters for one patient can be explained by the distribution for another?

In Classical Test Theory (CTT) [10] one of the most important concepts is **reliability**: this is generally understood to be the extent to which a measure is stable or consistent. It is defined as the squared correlation coefficient between observed and true scores. **Correlation** ρ determines to what extent a change in one variable, $x = \{x_1, x_2, \dots, x_i, \dots, x_n\}$ (true scores), influences the change in another, $y = \{y_1, y_2, \dots, y_i, \dots, y_n\}$ (observed scores).

$$\rho = \frac{1}{n} \cdot \frac{\sum_i (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_k (x_i - \bar{x})^2 \cdot (y_i - \bar{y})^2}}$$

where $\bar{x}$ and $\bar{y}$ are averages of x and y correspondingly.

In most cases correlation is used to determine relationship between variables. In this case correlation is used to define the new variable: reliability. We follow the same approach to determine persistency of distribution of weights of the diagnostic parameters for these two patients. In other terms, we want to determine similarity between vectors representing weights of diagnostic parameters of two patients. In our case correlation coefficient ρ between these two vectors determines to what extent distribution of these weights for one patient influences the distribution of these weights for another. To find out persistency of distribution of weights for all patients we have to average these correlation coefficients for all patients of a psychiatrist.

Definition: ***Experience*** is defined as the average of correlation coefficients ρ_{ij} between vectors of weights of the diagnostic parameters (*n* is total number of patients):

$$Experience = \frac{1}{n \cdot (n-1)} \cdot \sum_{i=1}^{n} \sum_{j=1}^{n} \rho_{ij}$$

where *n* is total number of patients and ρ_{ij} is the correlation coefficient between weights w_{ik} and w_{jk} of the diagnostic parameters *k* (*k = 1,..m*) for patients *i* and *j*:

$$\rho_{ij} = \frac{1}{m} \cdot \frac{\sum_{k-1}^{m} (w_{ik} - \overline{w}_i) \cdot (w_{jk} - \overline{w}_j)}{\sqrt{\sum_{k-1}^{m} (w_{ik} - \overline{w}_i)^2 \cdot (w_{jk} - \overline{w}_j)^2}}$$

where $\overline{w}_i$ and $\overline{w}_j$ are averages of weights for patients *i* and *j*.

The smaller value *Experience* is the more approaches psychiatrist tries in diagnostic procedures and, therefore, the more varied his/her tactics is. This comes with experience (unfortunately, not always). Therefore, we use this parameter as a proxy for it.

It was noted that *Experience* determines dynamics of changes of distributions of weights and therefore is considered as a dynamic parameter.

In [Simon] it was shown that human beings have significant information-processing limitations (e.g., attention, memory, and perceptual constraints) and therefore, have to use simplifying heuristics. However, these heuristics, instead of being viewed as erroneous, can be seen as powerful and effective strategies for making many everyday decisions.

These heuristics can be revealed in tactics used by psychiatrists. One of commonly used heuristics is to make diagnosis by assigning highest weights to diagnostic symptoms that have highest grades. In other words once it is established that patient has some severe symptoms then only these symptoms determine the diagnosis. This heuristics can be associated with caution.

To find the quantifying measure of this heuristics we have to define parameter that captures extent of dependence of weights of diagnostic symptoms from values of symptoms themselves. Here we also use correlation but in this case the resulting measure is static as it doesn't depend on number of patients and can be calculated even if there is only one patient.

Definition: ***Caution*** is defined as the normalized sum of correlations between grades of symptoms and their weights

$$Caution = \frac{1}{n} \cdot \sum_{i=1}^{n} \rho_i$$

where ρ_i is the correlation coefficient between grades and their weights for patient *i*; *n* is total number of patients.

If a doctor decides that the weight of a particular symptom should be high *only* because the corresponding grade is high then the the correlation coefficient is high. It can be interpreted that this doctor is risk-averse. If a doctor determines that the weight of any characteristic should be independent of its corresponding grade then the correlation coefficient should be low. It can be interpreted that such a doctor is likely to be risk-taking.

Another heuristics that can be considered is to base a diagnosis on selected symtoms and to large extent disregard others. In other words, weights of symptoms will vary little from one patient to another. In such a case the diagnosis will depend on only these selected diagnostic symptoms. Weights of these (as well as other) symtoms will vary but little. Thus tactics based on this heuristics is as follows: if a psychiatrist changes weghts of different characteristics easily as he/she moves from one patient to another then his/her tactics can be viewed as flexible. If, on the other hand, a doctor changes weghts little then his/her tactics is rigid. Therefore the key measure will be differences between weights. To quantify this heuristics we use absolute values of differences between weights of symptoms of different patients. For every two patients we have to take the average of absolute values of differences between weights for all symptoms; to calculate the measure for all patients we have to normalize the result.

Definition: ***Flexibility*** is equal to the normalized average of the sum of absolute values of differences between weights for all patients:

$$Flexibility = \frac{1}{n^2} \cdot \sum_{j=1}^{n} \sum_{k=1}^{n} \frac{1}{m} \cdot \sum_{i=1}^{m} abs(w_{ij} - w_{ik})$$

where w_{ij} is the weight of symtom *i* for patient *j*; abs (x) is the absolute value of x; *m* is the number of symptoms; *n* is the number of patients.

Flexibility depends on dynamics of changes of weights for different patients and, therefore, similar to *Experience* is a dynamic parameter.

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