Diagnosis in Psychopathology: proposal of a dimensional model using Bayes' theorem and Set Theory

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Abstract

Two main lines of work condense the research program of psychopathology as a clinical science: the study of brain structure, organization, and functioning, and the strengthening of emerging statistical models for diagnosing mental disorders. The first line arises from the failure of psychopathology to produce neurobiological and genetic objects that solve the problem of pathogenic factors at the level of etiology; the second line is linked to the drawbacks that characterize categorical classifications, especially with the reliability of diagnostic instruments. Both obstacles have an impact on the performance of the clinician in his work since, if the diagnosis is a central axis for the understanding and treatment of the disease, given the epistemological and methodological conditions of psychopathology, the professional immersed in its field is not only more prone to a higher rate of diagnostic errors than physicians treating other pathologies but also tends to be less aware of them. In this situation, heuristics are weaker, and using complex reasoning is more necessary. In this research a proposal for psychopathological diagnosis is tested using Bayesian reasoning and set theory; by considering disorders as random events composed of other random events, the dimensionality of the symptoms that concur in the intersection spaces at different sample points makes possible the construction of criteria using set-builder notation.

Keywords

Clinical reasoning, Bayesian reasoning, set-builder notation, psychopathology, diagnosis.

Diagnosis has a central role in the clinical setting since it converges explanations of a phenomenon determined by a of man variables, as well as the ability to predict and prognosticate about the course of that phenomenon given its inherent characteristics or the interventions employed for its modification (Peterson et al., 2019a).

Following the article published by the Institute of Medicine just over two decades ago elucidating the correlation between diagnostic errors and total medical errors, as well as

their high impact on morbidity and preventability (Institute of Medicine, 2000), a multiplicity of studies has emerged that address the factors that impact diagnostic errors (Clark et al., 2018; Croskerry, 2003; Fletcher et al., 2020a; Khan et al., 2022; Norman et al., 2017; Phua & Tan, 2013; Royce et al., 2019)

These studies articulate incident variables in different proportions (Clark et al., 2018), including 1) environmental factors related to issues of budget allocation or distribution, material resources or organizational climate within healthcare institutions, and other public policy issues; 2) cognitive factors referring to information processing errors, and 3) factors related to lack of experience and academic preparation.

Likewise, in this articulation there is a tendency to emphasize environmental factors, a tendency that masks the role of errors in clinical reasoning or lack of knowledge; in other words, clinicians are often unaware of their responsibility for the error (Norman et al., 2017). In this tenor, and understanding the centrality of clinical diagnosis given its explanatory power, and heuristic value, it is convenient to elucidate what factors are involved in its elaboration; i.e., what is clinical reasoning and how it is composed.

Royce and his working group (2019b) postulate that clinical reasoning is a competence where theoretical, procedural, and attitudinal knowledge is materialized for constructing a diagnosis and formulating intervention strategies for its treatment. Likewise, regarding its composition, they place a hierarchical structure of two levels, with evidence-based clinical knowledge, heuristics, and clinical epidemiology concurring in the first level, while Bayesian reasoning, inductive reasoning, and hypothetic-deductive reasoning concur in the second level.

The hierarchization into levels is in line with the dual processing theory, which holds that there are two systems for information processing, where System 1 is characterized by processes of rapid, intuitive cognition, pattern recognition, and using heuristics and mental shortcuts; while reasoning in System 2 is rather analytical and based on metacognition strategies (Kahneman, 2013).

Considering this conceptual framework and to correct the tendency to mask the clinician's responsibility, proposals have emerged to locate in their correct dimension the incidence of cognitive biases and shortcomings in clinical knowledge as well as approaches to correct them and increase the accuracy and precision of the diagnosis to contribute to the increase of its explanatory power and predictive value (Norman et al., 2017).

The main advances that have been made in the field are as follows: two dimensions of diagnostic error are recognized: error in processing and error in labeling (Newman-Toker, 2014); a series of cognitive response dispositions (CDRs or cognitive biases) that can lead to diagnostic error have been identified and defined, and strategies to reduce their incidence and consequently their impact have been proposed (Croskerry, 2003), as well as studies on the effectiveness of their implementation.

From these studies it can be highlighted that a) in clinical reasoning, System 1 and System 2 operate sequentially (Kahneman, 2013); b) both systems can lead to diagnostic error (Royce et al., 2019); c) strategies focused on educating clinicians to recognize cognitive biases have shown little effectiveness (Royce et al., 2019); d) in typical cases, clinician experience has an inverse relationship with diagnostic error, in contrast to the novice clinician (Norman et al., 2017); e) in atypical cases, the diagnostic error rate between

experienced and novice clinician does not show a significant difference (Norman et al., 2017); f) increasing the time to make the diagnosis does not immediately lead to a reduction in the probability of error (Khan et al., 2022); g) strategies for reorganizing information (e.g. by employing feedback to the clinician solving a clinical vignette) have had greater efficacy than strategies aimed at educating in the recognition of cognitive biases (Norman & Eva, 2010); h) trials of teaching and employing Bayes' theorem are modest but show some efficacy (Bours, 2021; Brush et al., 2019a; Proeve, 2009; Rottman, 2017); i) more research is needed for each of the items.

Now, all these questions and developments have arisen within medicine for the treatment of the phenomena it calls *disease.* But what about the diagnosis of mental disorders? What is their status? Psychopathology is lagging because, in addition to all the variables mentioned as contributing to the emergence of diagnostic error, there are also factors inherent to the epistemological and methodological dispositions of its field (Bach et al., 2022a; Fletcher et al., 2020a).

Two points stand out in this inherency, a) reducing the explanatory power of diagnosis regarding its weak articulation with etiological factors of mental disorders (Barukel & Stolkiner, 2018a; Borsboom, 2017a), and b) a delay in the migration towards dimensional models, such that psychiatric taxonomy drags the problems of the categorical approach (Widakowich, 2012a).

On the first point, insofar as psychopathology is circumscribed in the medical model, it is biased from the latter since if the diagnosis of illness typically carries with it the pathogenic element that caused it, mental disorders are constellations of symptoms that are empirically associated by typically unknown causes (McNally et al., 2015a).

From the second point, the constitution of mental disorders as discrete units or categories that can be diagnosed if previously established fixed criteria are met leads to an overlapping of mental disorders and comorbidity that negatively impacts the reliability of diagnostic manuals that belong to the categorical psychiatric model (Bach et al., 2022a; First, 2014; Peterson et al., 2019a), so although both the *American Psychological Association's* (*APA*) Diagnostic Statistical Manuals (DSM) and the *World Health Organization's* (*WHO*) International Classification of Diseases (ICD) were able to establish stable unanimity in psychiatric nomenclature, their attempt to resolve problems in processing and diagnostic labeling are underdeveloped compared to medical research (Fletcher et al., 2020b; Keeley & Gaebel, 2018).

Thus, Croskerry (2003) was not wrong when he created the *Psych-out error* bias, where he does not specifically mention any other bias than the *Fundamental attribution error* (previously defined as the tendency to blame patients for their condition) and rather what is significant is his assertion that psychiatric patients are particularly vulnerable to all the CDRs described in the list, in addition to other errors in treatment that tend to exacerbate the pathological condition.

Additionally, the decline of the process in explanatory power has led to a decrease in the heuristic value of psychiatric nosology, which can be reflected not only in the problems of reliability of diagnostic categories (Berta et al., 2022a; Kotov et al., 2017a), but also in the failure to accomplish medicine’s task, in its neurological branch, to produce and articulate neurobiological and genetic objects that aid in the construction of the objectified diagnosis (Schultze-Lutter et al., 2018).

Faced with this situation, several professionals in the health field have undertaken various strategies to reverse this situation; these strategies have as a common denominator testing with dimensional models for the construction of a new psychiatric nosology; some of these models are the *Hierarchical Taxonomy of Psychopathology (HiTOP)* (Kotov et al., 2017a), the *Research Domain Criteria* (*RDoC)* (Cuthbert, 2015) or the *Network Approach to Mental Disorders* (Berta et al., 2022b; Borsboom, 2017b; McNally et al., 2015b).

APA and WHO have also implemented strategies to reverse this situation. One of them was the launch of the Differential Diagnostic Handbook, which, by not solving the categorical problem, fails in its purpose (Frances & Nardo, 2013a) by asserting that as mental disorders are rarely mutually exclusive, "diagnostic comorbidity is the default position" (First, 2014), confusing concurrence between symptoms with comorbidity between disorders.

Another action undertaken by both APA and WHO has been the gradual migration of their nosology towards the dimensional model; for example, the integration of *Pervasive Developmental Disorders* in DSM-IV-TR, to *Autism Spectrum Disorder*, in DSM-5 (American Psychiatric Association, 2014), or the inclusion in ICD-11 of five dimensions for the diagnosis of *Schizophrenia and other primary psychotic disorders* (Department of Mental Health and Substance Abuse, 2021) and the substantial change in the way *Personality Disorders and related traits* are diagnosed (Department of Mental Health and Substance Abuse, 2022). Notwithstanding these efforts, little improvement has been shown in empirical studies on using both manuals (Bach et al., 2022a; Cristina Amoretti & Lalumera, 2019; Frances & Nardo, 2013b; Kamens et al., 2017; Keeley et al., 2016; Kraemer et al., 2012; Peterson et al., 2019b).

It is in this light that this research is inscribed as a proposal to "recover the experience of suffering" (Barukel & Stolkiner, 2018b) finding new paths that will contribute to the construction and solidification of diagnostic models that reflect a reliable nosology and that, then, the psychopathological clinic emerges with a renewed explanatory power and heuristic value to account for a highly prevalent phenomenon today, namely mental disorders. This proposal takes as a referential framework using descriptive statistics and set theory to advance in the construction of a set-builder notation model of mental disorders.

Method

Selection of mental disorders and framing within the dimensional model

Given the hegemonic status of the DSM-5 and ICD-11 taxonomy for psychiatric nomenclature (Romelli et al., 2016), as well as the fact that both have realized the need to migrate focus, we decided to insert the model in the WHO nosology since, even with its limitations, there, the migration to the dimensional approach has permeated more clearly (Bach et al., 2022b).

Afterwards, from *HiTOP* (Kotov et al., 2017b) we adopted the concepts of *dimensions* to refer to symptoms and their nature as psychopathological continuums reflecting individual differences, of *clusters* as constellations of symptomatic manifestations that are close to

each other, of the *syndrome* as an analog of *mental disorder* or composites of symptomatic constellations close to each other, of *spectrum* as constellations of syndromes, and *super-spectra* to denote super-wide dimensions of spectra.

Given the experimental nature of the model we propose, we decided to test it by taking a sample of mental, behavioral, and neurodevelopmental disorders, which was composed of *Schizophrenia and other primary psychotic disorders*, *Mood disorders,* and *Anxiety or fear-related disorders*. This total group of disorders was conceived as a super-spectrum, where each category is formed as a spectrum composed of syndromes, and which in its totality clearly shows the dimensional character of the clusters that form them.

For instance, in *Primary psychotic disorders*, in addition to positive symptoms, there are mood symptoms; likewise, in *Mood disorders*, there may be hallucinations or delusions, psychomotor or other cognitive symptoms characteristic of psychotic disorders, in addition to anxiety; and in *Anxiety and fear-related disorders* there may be symptoms of the affective cluster, cognitive-behavioral cluster, or neurovegetative cluster similar to depression or some presentations of psychotic disorders (American Psychiatric Association, 2014; World Health Organization, 2023).

Mental disorders and set theory.

Once the mental disorders were selected, we decided to adopt the *Set Theory* for their organization and treatment, so that the elements that compose them were subject to the principles of that theory (Miller et al., 2013). Thus, the set of all mental disorders is the *Universe*.

The disorders on each spectrum are the Sets; for Primary Psychotic Disorders: *Schizophrenia*, *Schizoaffective Disorder*, *Schizotypal Disorder*, *Acute and Transient Psychotic Disorder*, and *Delusional Disorder*; for Mood Disorders: *Bipolar Disorder Type I*, *Bipolar Disorder Type II*, *Cyclothymic Disorder*, *Single Episode Depressive Disorder*, *Recurrent Depressive Disorder*, *Dysthymic Disorder*, and *Mixed Depressive and Anxiety Disorder*, and; for Anxiety or Fear-Related Disorders: *Generalized Anxiety Disorder*, *Panic Disorder*, *Agoraphobia*, *Specific Phobia*, *Social Anxiety Disorder*, *Separation Anxiety Disorder*, and *Selective Mutism*.

Sets have a *Cardinality* $n(A)$ that translates into the number of Elements or signs and symptoms that conform to them. Besides, the behavior between mental disorders can be understood through the possible relations of sets; thus the *complement* $A' = \{x | x \in U \notin A\}$, the *intersection* $A \cap B = \{x | x \in A \ y \ x \in B\}$, the *union* $A \cup B = \{x | x \in A \ o \ x \in B\}$, the *difference* $A - B = \{x | x \in A \ y \ x \notin B\}$, and the *Cartesian product* $A \times B = \{x, y | x \in A \ y \ y \in B\}$. Finally, listing each element that composes them, or set-builder notation, making explicit the properties for the grouping can write the elements of the sets.

For each mental disorder, the ICD-11 (World Health Organization, 2023) includes in its navigator the *parent entity* or spectrum to which the disorder belongs, a general *description* of the disorder, *exclusions*, *post-coordination*, and the system that allows adding "details" (in the case of mental disorders, details include symptomatic manifestations and symptomatic periods), *diagnostic requirements*, which in turn are divided into *essential (required) features*, *course specifiers*, *additional clinical features*, *boundaries with normality (threshold)*, *course features*, *developmental presentations*,

culture-related features, *sex- or gender-related features*, and *boundaries with other disorders or conditions (differential diagnosis)*.

Each of these points includes relevant information to determine which are the elements of the sets and what qualities they have; hence, we can find that depending on the mental disorder, the value of the signs and symptoms varies (Maung, 2016), so it was decided to hierarchize them into three levels, *Nuclear Features* (*NF); Essential Features* (*EF*) that, however, are not nuclear, and *associated Features* (*AF*); moreover, ICD-11 reports the typical presentation of the symptoms in time and severity, e.g., with minimum or maximum thresholds for diagnosis, or specifications of fluctuability and type of onset (acute or incident).

To illustrate, in the diagnosis of Schizophrenia, the ICD-11 requires that at least two symptoms be present almost all the time for one month or more and that at least one of the symptoms should belong to items "a)" through "d)", which refer to 4 of the 5 available positive symptoms: *hallucinations*, *delusions*, *disorganized thinking*, and *experiences of influence, passivity, or control*; note that *disorganized behavior* is not counted here. Then, the other symptom that must go with can either be another positive symptom or another of the elements described in items "e)", "f)" and "g)", which are *disorganized behavior* (the fifth positive symptom), *negative symptoms*, and *psychomotor symptoms*. Finally, the general description of Schizophrenia and additional clinical features detail other symptoms that may occur in this disorder, such as *cognitive impairment*, *circadian cycle reversal*, *anxiety*, *agitation*, and *depressive symptoms*.

If we order the symptoms according to the three-level hierarchy, the first four elements occupy the *NF* rank; disorganized behavior, negative symptoms, and psychomotor symptoms are in the *EF* rank, and; anxiety, depression, cognitive impairment, and other neurovegetative symptoms integrate the *AF* rank.

With this formulation, we tested a first model of set-builder notation by intent using as an example the set Schizophrenia (6A20), where *S* = positive symptoms, *N* = negative symptoms, and *P* = psychomotor symptoms.

$$6A20 = \{x | x = \geq 2;\ \exists x1,\ \exists x2 \mid \exists x1 \in S;\ \exists x2 \in S \cup N \cup P\}$$

With this first test, assuming that in the presentation of the clinical case $|6A20| = 2$, we observe the complexity of mental disorders when considering that these two elements one of them belongs to *S* and the other belongs to *S* or *N,* or P, since

$$C(n,k) = \binom{n}{k} = \frac{n!}{k!\,(n-k)\,!}$$

And that is in the minimum necessary range for Schizophrenia, $C_{total} = C(4,1) \times C(18,1)$ since $|NF| = 1$ $|EF| = 1$ there are at least 72 possible combinations. If we include in the count the occurrence of only one associated symptom ($|AF| = 1$), the possible combinations would be 1,656.

As this is the structure in which mental, behavioral, and neurodevelopmental disorders are commonly presented in ICD-11 Chapter 06. In addition to the three-level hierarchy, the following adjustments were made to organize the elements of the sets: a) using Set Theory

was complemented with Descriptive Statistics and Conditional Probability; b) defined ranges of time were established; c) defined ranges of symptomatic severity were established.

For item "a)", we went from considering mental disorders as simple conglomerates of symptoms to understanding them as events. Being subject to the principles, axioms, and theorems of probability (Manrique, 2005)). Within them, we find that the configuration of mental disorders, made up by signs and symptoms from the dimensional approach, can be considered random events in that their presentation is heterogeneous. That the totality of this heterogeneity is part of a *sample space* (Ω), and that depending on how it is presented, it can be homologous of the spectrum or the super-spectrum; that when working with a subset of the sample space this is called $\sigma - algebra$; that ω is a *sample point*, meaning a random result; that in consideration of the heterogeneity of the symptom regarding the determinants of its *CN*, *CE* or *CA* value, and its temporal or severity presentations, it makes up both an *elementary event*, insofar as it consists of a single sample point and a *composite event* when it is made up of more than one sample point.

For the specification of the symptom as an elementary event, an understanding of its conceptual definition that individualizes it is required; i.e., hallucinations and delusions even though both are positive symptoms that belong to the cognitive-behavioral cluster, the first implies an alteration of perception while the second implies an alteration of thought (Sadock et al., 2015). On the other hand, for its value as a composite event, we chose to establish the following sample points within the symptoms themselves:

- According to their value within the hierarchy, the symptoms can be
    - P1 if they have *NF* value.
    - P2 if they have *EF* or *AF* value.
- According to their presentation, over time and the minimum symptom durations for a given mental disorder to be diagnosed, six-time ranges were established:
    - 0 to 6 days
    - 7 to 13 days
    - 14 to 30 days
    - 31 to 179 days
    - 180 to 729 days
    - 730 days and over
- According to their severity, two ranges were established
    - Mild
    - Severe

Before the large consortium that is formed by the union in the large spectra and super spectra, symptoms cross different dimensional clusters. In ICD-11 we have several of them; for example, within Primary psychotic disorders there are *positive symptoms*, *negative symptoms*, *psychomotor symptoms*, *depressed mood symptoms*, *manic mood symptoms*,, and *cognitive symptoms*; for Personality disorders, there are traits of *negative affectivity*, *detachment*, *dissocial behavior*, *disinhibition*, *anancastic features*, or *borderline pattern*; or for depressive episodes within mood disorders, there are *affective*, *cognitive-behavioral* and *neurovegetative* clusters.

Since the three clusters of depressive episodes conveniently fit the dimensionality of the symptoms of mental disorders, it was decided to adopt them as the transverse axis. Finally, the ICD-11 diagnostic requirements commonly condense in one vignette several

symptoms that in other mental disorders may be separate (for example, in the essential features of the Manic episode, *irritability* appears in the same vignette together with *euphoria or expansiveness of mood*, whereas in Generalized anxiety disorder, it is shown discretely); Likewise, symptoms may be named differently from one disorder to another but refer to the same entity (e.g., *anhedonia* in item "c)" of Schizophrenia versus $markedly\ diminished\ interest\ or\ pleasure\ in\ activities$ from the Depressive episode affective cluster).

To resolve this situation, $\sigma - algebra$ composed of 19 mental disorders, a total of 106 symptoms were discretized as elementary events, of which 23 belong to the affective cluster, 51 to the cognitive-behavioral cluster, and 32 to the neurovegetative cluster. Mental disorders were plotted as categories of analysis and symptoms as variables. Thus, the general structure of the matrix was constructed (Table 1).

Determination of ω and test of Bayes' theorem

Given the scientific nature to which psychopathology aspires, we considered the value of the diagnosis in its hypothetical nature, recognizing uncertainty as an inherent feature of the clinic of mental disorders. On the other hand, we start from the assumption that in clinical reasoning calculating probabilities is usually employed to determine the decantation of the diagnostic label; however, clinicians do not usually make explicit the determinants of such calculation (Brush et al., 2019b). It is in this vein that in the medical field not only has Bayesian reasoning been included as a feature of the clinician's cognitive processing (Royce et al., 2019a) and its management has been tested to observe variations in that medical field (Bours, 2021b; Brush et al., 2019b; Rottman, 2017b), but also applying Bayes' rule, has permeated the field of psychopathology (Crawford et al., 2009; Proeve, 2009b; Tso et al., 2021a). Thus we will employ Bayesian reasoning for the proposal of our diagnostic model.

To be able to do so, it was necessary to establish the probabilistic values of each symptom; that is, its value in each ω. Since events are sets (Mora & Nieto, 2019), the set of all events (the Universe of mental, behavioral, and neurodevelopmental disorders) is called *parts of* Ω, the probability of that universe, $p(\Omega)$ and the pair $(\Omega, p(\Omega))$ is called the *probabilistic space*. Finally, *probability* is defined as "an application, *p*, of $p(\Omega)$ on a real line $(\Re)$ such that to each event, *A*, corresponds its theoretical measure of occurrence, *p(A)*" (Manrique, 2005).

Therefore, we initially worked to obtain the intrinsic probability of *NF* symptoms without considering prior probabilities, for example, in the case of primary psychotic disorders:

- For Schizophrenia and Acute and transient psychotic disorder, at least one *NF* symptom out of a possible four is required. Thus a value of $P_1 = .25$ for each of them.
- Delusional disorder necessarily requires the presence of *delusions* as an *NF*, in addition to not presenting another positive symptom (except *hallucinations* when these are secondary to the delusional idea), so $P_1 = 1$.
- For Schizotypal disorder, *NF* symptoms are inferred to be *asociality* and *mild disorganized thinking*, present concurrently, so $P_1 = 1$.
- For Schizoaffective disorder, in addition to the value of *.25* on *P1* for four positive symptoms, requiring the presence of a *Manic episode*, a *Depressive episode*, or a

Mixed episode, the *NFs* are *depressed mood* and *anhedonia* for depression and *euphoria, irritability or expansiveness of mood* plus *increased activity or subjective feeling of increased energy*, for mania; these symptoms can manifest in a pure episode (either depressive or manic) or a mixed episode; therefore $P_1 = .66$.

Afterwards, the intrinsic probability of *EFs* and *AFs* was tested and their theoretical measure of occurrence was assigned the place in P2. Continuing with the example of primary psychotic disorders:

- For Schizophrenia there were 18 symptoms at the *EF* level, 4 positive symptoms (the three that theoretically were not found in a random event in *P1* plus *disorganized behavior*) seven psychomotor symptoms, and seven negative symptoms, so that $P_2 = .05$ for each of them. On the other hand, a total of 23 cognitive, behavioral, and neurovegetative symptoms were counted at the *AF* level, which added to the 18 *EF* symptoms giving a total of 41, so that for each of them $P_2 = .024$.
- For Acute and transient psychotic disorder, negative symptoms were excluded, so the total number of *EF* and *AF* symptoms was $P_2 = .052$.
- For Schizotypal disorder, the *EFs* are 9 and are mainly composed of sporadic and mild positive symptoms (e.g., hallucinations), cognitive symptoms, and negative symptoms, so $P_2 = .11$; as for the *AFs*, these are characteristic symptoms of depressive mood; so $P_2 = .05$ is their assigned value.
- In delusional disorder there are no *EF* elements and all the symptoms that can concur with the delusional idea are *AF*, including hallucinations. Thus, this positive symptom is added together with the symptoms of depressed mood and manic mood to give value $P_2 = .05$.
- In Schizoaffective disorder, negative symptoms, psychomotor symptoms, and psychotic symptoms at the *EF* level were assigned the same value as in Schizophrenia $P_2 = .05$; however, depressive mood and manic mood symptoms were also assigned at the same level; whereas for the depressive episode, 3 symptoms are required to go with the two necessary *EFs* (sad mood and anhedonia) out of a total of 8, $P_2 = .37$. In the case of the manic episode, the ICD-11 does not include a minimum specification of symptoms for the *EF* level (although it does for *NF*), hence, it was decided to adopt the DSM-5 criterion of 3 symptoms at this level, so $P_2 = .42$. Finally, the other associated symptoms were also assigned the same value as schizophrenia $P_2 = .024$.

This trial was extended to the analysis of symptoms at the three possible levels occurring with different intrinsic values within Mood disorders and Anxiety or fear-related disorders.

Once these values were obtained, they were treated as dependent events $P(A \cap B) = P(A) \times P(B|A)$; $P(A \cap B) = P(B) \times P(A|B)$ so that their calculation was complemented by considering the probability of occurrence of the symptom as multiplied by the prevalence of each disorder in which it is known to occur. Thus, for example, if the base rate of Schizophrenia is .007 in the overall population, hallucinations, delusions, disorganized thinking, and experiences of passivity and control, have an *NF* value of $P_1 = .00175$ and an *EF* value $P_2 = .00035$.

Afterward, this probability was distributed into different ranges of temporality and severity. Continuing with the example of schizophrenia, if both *NF* and *EF* symptoms have to last at least 1 month, the three first ranges have a value $P_1 = 0; P_2 = 0$. Also, the information contained in the general description of the disorder, in the essential features, in the course specifiers, in the developmental presentations, in the additional clinical features, in the boundaries with normality and with other mental disorders, as well as in the data coming from the DSM-5, it can be inferred that of the remaining three ranges, In the fourth range, the highest probability is concentrated, in the fifth it decreases considerably and in the sixth, it is practically nil, so that a value of 80% of positive symptoms occurring in the range of 31 to 179 days, 19% that they occur in the range of 180 to 729 days, and 1% that they occur in the range of 730 days or more was assigned.

As for severity, the information contained in the same sources can lead to the inference that this variable has a directly proportional relationship with the temporal distribution, so that when the probability of the symptom occurring in a temporal range increases or decreases, the severity variable behaves in the same way. Therefore, it was determined that both *NFs* and *EFs* in ranges 4, 5, and 6 had a severity distribution of 70% severe - 30% mild, 30% severe - 70% mild, and 10% severe and 90% mild, respectively.

Regarding the *AFs*, it was inferred that the distribution over time is inverse to the *NF* and *EF* elements since even when symptoms may occur, they happen sporadically, fluctuating and generally mild, so only ranges 1, 2, 3, and 4 received the values of 40%, 30%, 25%, and 5%, with severity in each severity distribution in each of them of 40% severe - 60% mild; 30% severe - 70% mild, 10% severe - 90% mild and 1% severe - 99% mild, respectively.

Having applied this reasoning and calculated the probabilistic value of each symptom regarding its intersection with a mental disorder as a dependent event, a database was constructed in which the values of each element were ordered in a table that can filter the symptom as a composite event according to the cluster to which it belongs, its time, its severity or its value as *P1* or *P2* (Table 2). In the same manner, a dynamic table was constructed where the total probability theorem was applied

$$P(A) = \sum_{i=1}^{n} P(A|B_i)\, P(B_i)$$

to obtain the mathematical result of the ratio of the probabilities of the symptoms to the conditional probabilities of the symptoms given in $\sigma - algebra$, i.e., in the set of mental disorders as mutually exclusive and exhaustive events (Table 3).

Relying on the $P(A \cap B)$ data as the probability of the intersection between the symptom as it was considered $P(B)$ as the probability of occurrence of the disorder in the overall population, $P(A|B)$ as the probability of the symptom in the mental disorder event, $P(A)$ as the total probability of the symptom in $\sigma - algebra$, as well as or the variation of the symptom in the different sample points, we proceeded to test for the predictive value of the symptoms with the formula of Bayes' theorem

$$P\left(A_k|B\right) = \frac{P\left(B|A_k\right) \times P\left(A_k\right)}{\sum_{i=1}^{n} P\left(B|A_i\right) \times P\left(A_i\right)}$$

For illustration, to resolve this question, "Given that the clinician determines the existence of hallucinations in a case, how likely is it that the case can be diagnosed as Schizophrenia? Considering that the overall population prevalence of this mental disorder is .007, that the conditional probability of hallucinations in schizophrenia is .002, and that the total probability of hallucinations in all mental disorders is .009", we substitute the data and apply the formula

$$P(B|A) = \frac{.002 \times .007}{0.009}$$

So the probability of being diagnosed with Schizophrenia given that the patient shows hallucinations is .001 or .1%. Now, what if the clinician also determines the existence of delusions and disorganized thinking? The probability increases to .6%. Applying this model, different configurations that included different levels of discrimination were tested; for example, with the case just described, the first question was not for Schizophrenia, but for the probability of presenting a Primary psychotic disorder; likewise, the values of the equation were modified to consider differences in severity, time, and hierarchy such as *NF*, *EF*, or *AF*.

Discussion

To the extent that psychopathology is part of the clinical field, diagnosis plays a central role in the practice of all those who deal with mental disorders. In the same way that health professionals, whose labor is focused on the prevention and treatment of illness in other branches and presentations, the clinician must be careful when formulating his or her impression of each case with which he or she intervenes.

In the realm of medicine, a research program has been developed that systematically integrates the variables that determine the decantation of the diagnostic process in labeling, considering conscientiously what happens when the impression was erroneous since the negative effect this causes for the purposes which the physician participates has been elucidated, namely, to understand the mechanisms by which disease arises, to predict its natural course according to certain conditions, to forecast the effects of different types of interventions for therapeutic purposes and, ultimately, to seek to reduce morbidity and mortality rates and increase the quality of life.

If, even with this systematized set-up, medical research has a long future regarding rectifying the error rate in diagnosis, the situation is even more complex in psychopathology, which can be associated with multiple variables that are related to each other in different ways and forms. First, there is no systematized program of investigations of the rate of diagnostic errors in psychiatry or clinical psychology, nor their impact on morbidity and mortality in both the hospital population and the general population.

There is also no systematization of studies on the biases and errors of cognitive processing, of the adequacy or inadequacy of curricular programs in professional training

centers according to the needs that empirical evidence demands. What exists is the criticism of public policies that reflect in the conditions of the spaces where mental health is treated, for example, with issues such as the number of psychologists or psychiatrists, the time the professional has to diagnose and attend to each patient, the number of psychiatric beds in general hospitals, the proportion of hospitals in the most urbanized areas to the detriment of rural areas, among others.

Furthermore, if to define is to limit (Wilde, 1890/2017), the high comorbidity of mental disorders and the unreliability of diagnostic systems reflect a problem of definition of the operators of psychiatric nosology. If it is true that, as Widakowich (2012b) states, paraphrasing Hempel, sciences commonly start with categorical classifications to then evolve to dimensional classifications, psychopathology is at a young stage. This statement is in line with the facts provided by reality, as both the DSM and the ICD show in their latest editions a gradual trend for the migration of models, or that the APA (2023) in the *Call for Papers* of the *Journal of Psychopathology and Clinical Science* shows the two major areas of clinical research: the mapping of brain structure, organization and functioning to produce neurobiological and genetic objects that facilitate the diagnosis and treatment of mental disorders, as well as the robustness of the statistical models created by *HiTOP* and *RDoC* for the clinical management of heterogeneity in psychopathology.

To summarize these points, then, in the generality of the current state of the field, if it is true that the physician is prone not to notice their mistakes when diagnosing the disease, the clinician who diagnoses mental disorders is even more susceptible. Consequently, the diagnostician shouldn't rely too much on heuristics and System 1, even when the case being analyzed is a typical one, and even more so when it is a complex case.

In this scenario, treating the formulation of the diagnosis as a hypothesis is crucial since in this regard uncertainty is accepted as an intrinsic feature of the clinic; once these first approximations are generated, the clinician aims his evaluation to investigate exhaustively through the mental state examination, clinical history, consultations with other medical specialties, laboratory tests, and epidemiological data to obtain new information to support in the corroboration or refutation of these impressions.

For this corroboration or refutation procedure, other types of information processing are used, including Bayesian reasoning. Not only has its use been tested in medicine, but there is also a bibliography showing that this type of study has permeated into psychopathology, albeit with a lag. In addition to all the reasons that influence the difference between psychopathology and other branches of medicine, it can be inferred that this lag in using the Bayesian model is influenced by the type of epidemiological information currently available on mental disorders.

Thus, the DSM-5 and WHO publications provide vague information on the prevalence of disorders. In some of them, only the base rate of only certain countries is mentioned. In others only the prevalence in hospital settings is explicit, or in still others it is given in the general population but with very wide ranges; and when scientific publications on this subject are consulted elsewhere, the vagueness persists and is often contradictory to what was found in APA and WHO. In any case, statistical data on the typology, course, or severity of symptoms are practically non-existent, at least in systematic reviews.

Despite this, the work of the clinical researcher must be oriented towards overcoming these barriers, be it through epidemiological research, studies that address the rate of

diagnostic errors in psychopathology, its variables, and possible corrections, as well as continuing with the analysis of the environmental factors that determine the field.

The purpose of this study was to provide a reasoning model to reduce diagnostic uncertainty when considering the presence of a group of symptoms in a given clinical case. The model includes a rough but general way of assigning intrinsic values to symptoms according to ICD-11 and DSM-5 descriptions of mental, behavioral, and neurodevelopmental disorders.

These values were also related to the ambiguous and unreliable epidemiological information available. A calculation of these values as conditional probabilities was performed and thus Bayes' theorem could be used to test its usefulness as a predictive method for mental disorders given that certain symptoms are present at different sampling points.

Before this point, it had been possible to test a set-builder notation model of the disorders from their approach as sets composed of elements; the example provided was that of Schizophrenia $6A20 = \{x | x = \geq 2;\ \exists x1,\ \exists x2 \mid \exists x1 \in S;\ \exists x2 \in S \cup N \cup P\}$. With the introduction of the conceptual framework of descriptive statistics, mental disorders were no longer considered as mere sets and elements, but as composite events made up of another set of equally composite events.

In this approach, it becomes possible to introduce a mathematical function that assigns specific probabilistic ranges in the set-builder notation of disorders, which would end up shedding light on the problem of psychiatric comorbidity, insofar as dimensionality understands that the intersection of sets is an immanence of mental illness, but since the concurrence between symptoms should not be confused with the comorbidity of disorders, thinking of the intersection $\sigma - algebra$ as a subset of the sample space where different sample points coincide, would help to solve the problem.
The shape of this study can be well aligned with the operators used in the field of psychometrics, where sensitivity, specificity, and likelihood ratio can be obtained and inserted into the Bayesian equation, either when they refer to the reliability of a diagnostic test, or if these operators are adapted to the DSM-5 and ICD-11 diagnostic manuals themselves, and particularly to their symptoms. An idea is provided by Proeve (2009a) with the formula: the probability of the mental disorder given a certain sign or symptom is equal to the sensitivity of the sign or symptom given that mental disorder multiplied by the prevalence, and this result divided by the sensitivity multiplied by the prevalence plus one, minus the specificity multiplied by the prevalence, i.e.

$$P\left(MD|S = \frac{P\ (S|MD) \times P(MD)}{\left[P(S|MD) \times P(MD)\right] + \left[1 - P(\not{S}|\not{MD}) \times 1 - P(MD)\right]}\right)$$

Likewise, this study could be inserted in network analysis research in psychopathology, so that with the values of the sample points different matrices can be built that might be fed into different computer programs not only to observe their behavior on a graphical plane but also to obtain precise metrics that favor the testing of other demarcation criteria in the set-builder notation of mental disorders; for example, with the *betweenness centrality* operator.

Although the reasoning is complex, efforts are being made to simplify it and to insert it into the reality of clinical psychopathology (Tso et al., 2021b). In the future, software programs

shall be developed to simplify and streamline this process for efficiency in the construction of an objectified diagnosis of mental disorders.

Limitations

In this research, only a sample of the total number of mental disorders was considered; future studies should complete the analysis of the conditional probability of the symptoms of all the composite events in the sample space.

On the other hand, unlike previous editions of the diagnostic manuals, the delay in the publication of ICD-11 introduces a gap between the criteria for structuring the composition and organization of mental disorders; this study has focused on the approaches contained in the WHO manual while complementing the ambiguous information with data from the DSM-5. This supplementation was arbitrary and represents an important limitation of the study. A comparative investigation of applying the set-builder notation model using Bayesian reasoning with the DSM-5-TR analysis would be desirable.

Additionally, the assignment of the intrinsic probabilities of the symptoms in each mental disorder were arbitrary, as well as their probabilistic distribution in artificially constructed time ranges, and the severity ranges were limited to only two variables. Ideally, the valuation of symptoms as sample points should be supported by empirical evidence that makes these data formally explicit; even if it is inferred that the compositions of the essential characteristics required for the diagnosis of mental disorders in Chapter 6 of ICD-11 or Section II of DSM-5 are based on observing the frequency with which certain symptoms occur in different clinical settings, the value defined undergoes the same artificiality of the categorical models by overriding the heterogeneity of psychiatric manifestations; Thus, for instance, it is a mistake to assume a priori that hallucinations and delusions have the same theoretical extent of occurrence.

A further limitation stems from the separation of symptoms into discrete units according to their elementary event status; since there are elements that are undefined or only ambiguously defined, discrimination is biased. For example, is the *anhedonia* of negative symptoms in Primary psychotic disorders identical to the *markedly diminished interest or pleasure in activities* characteristic of Depressive episodes? If so, why was anhedonia incorporated into the negative symptoms and not into the depressive mood symptoms that are also found within the symptomatic manifestations of primary psychotic disorders? Another example of ambiguous delimitation happens with the *experiences of passivity and control; aren't* these complex forms of hallucinations or delusions?

An additional limitation of this work was that it did not sufficiently integrate the advances made by *HiTOP* and *RDoC* research, for example, with the decanting of the dimensions that have been classified here as *clusters*. Future studies will be able to insert the reasoning presented here into these research programs.

Finally, as noted by Proeve (2009a) the Bayesian model has its weaknesses, which, in order not to decrease its reliability, must be complemented with other statistical methods, such as the repeated sampling model for the construction of intervals.

Conclusion

Using Bayesian reasoning is plausible for explaining calculating probabilities made by a clinician when formulating a diagnosis. This reasoning can lead to an increase in the explanatory power and predictive value of psychopathology, having a favorable impact on the rate of diagnostic errors and their consequences on morbidity and mortality associated with mental disorders. Its insertion in the psychopathological field is still limited in that current epidemiological data on the characteristics and presentations of psychiatric disorders is ambiguous and incomplete. Nevertheless, with the available information, it is appropriate to conduct tests that prepare the ground for the construction and systematization of dimensional models for the diagnosis of psychopathologies. Uncertainty is a feature of sophistication, so knowing how to work with it is a milestone in developing clinical science.

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Tables

Table 1

General matrix structure

Dimension	Symptom	Time range	Severity	Hierarchy	MD_1	MD_2	MD_n
		1	L	P1			
				P2			
			G	P1			
				P2			
		2	L	P1			
				P2			
			G	P1			
				P2			
		3	L	P1			
				P2			
			G	P1			
$Cluster_x$	S_x			P2			
		4	L	P1			
				P2			
			G	P1			
				P2			
		5	L	P1			
				P2			
			G	P1			
				P2			
		6	L	P1			
				P2			
			G	P1			
				P2			

Note: In this structure, the first column contains three clusters: affective, cognitive-behavioral, and neurovegetative. Each cluster contains n symptoms (column 2), which in turn have a specific pattern of behavior over time (column 3), with a certain severity (column 4) and with a location in two levels according to their hierarchy as core symptom, essential symptom or associated symptom (column 4).

Table 2

Extract from the database by filtering ω

Dimension	Symptom	Time range	Severity	Hierarchy	6A20	6A21	6A22	6A23	6A24	6A70
C-B cluster	Delusions	1	S	P1	0	0	0	0,0001365	0	0
C-B cluster	Delusions	1	S	P2	0	0	0	0,00002839	0	0,00019444
C-B cluster	Delusions	2	S	P1	0	0	0	0,000273	0	0
C-B cluster	Delusions	2	S	P2	0	0	0	0,00005678	0	0,00005556
C-B cluster	Delusions	3	S	P1	0	0	0	0,0006825	0	0
C-B cluster	Delusions	3	S	P2	0	0	0	0,00014196	0	0,00001389
C-B cluster	Delusions	4	S	P1	0,00098	0,00042	0	0,000117	0	0
C-B cluster	Delusions	4	S	P2	0,000196	0,000084	0	0,00002434	0	0
C-B cluster	Delusions	5	S	P1	0,0000997	0,0000427	0	0	0,00126	0
C-B cluster	Delusions	5	S	P2	0,00001575	0,00000675	0	0	0	0
C-B cluster	Delusions	6	S	P1	0,00000175	0,00000075	0	0	0,00006	0
C-B cluster	Delusions	6	S	P2	0,00000175	0,00000075	0	0	0	0
Affective cluster	Depressive mood	1	S	P1	0	0	0	0	0	0
Affective cluster	Depressive mood	1	S	P2	0,0000272	0,00001152	0	0,00002839	0,000018	0
Affective cluster	Depressive mood	2	S	P1	0	0	0	0	0	0
Affective cluster	Depressive mood	2	S	P2	0,0000156	0,00000648	0	0,00005678	0,000012	0
Affective cluster	Depressive mood	3	S	P1	0	0	0	0	0	0,021
Affective cluster	Depressive mood	3	S	P2	0,00000425	0,0000018	0,000126	0,00014196	0	0,001
Affective cluster	Depressive mood	4	S	P1	0	0,001188	0	0	0	0,0105
Affective cluster	Depressive mood	4	S	P2	0,000000085	0,0009	0,000036	0,00002434	0	0,0005
Affective cluster	Depressive mood	5	S	P1	0	0,0001782	0	0	0	0,0035
Affective cluster	Depressive mood	5	S	P2	0	0,000135	0,000012	0	0	0,00175
Affective cluster	Depressive mood	6	S	P1	0	0,0000198	0	0	0	0
Affective cluster	Depressive mood	6	S	P2	0	0,000015	0,000006	0	0	0

Note: this database shows the values of one symptom of the cognitive-behavioral cluster (C-B cluster) and one symptom of the affective cluster at their different sampling points for primary psychotic disorders and depressive disorders. The symptoms' presentation is filtered in severe mode.

Table 3

Extract from the dynamic data table with total probability values.

Symptom	**∑ 6A20**	**∑ 6A21**	**∑ 6A22**	**∑ 6A23**	**∑ 6A24**	**∑ 6A70**
Constrained mood	0,00035	0,00015	0,00066	0	0	0
Blunted mood	0,00035	0,00015	0,00066	0	0	0
Psychomotor agitation	0,00035	0,00164932	0,0003	0,0004056	0,0001	0,09055556
Hallucinations	0,00209995	0,0008999	0,00066	0,0023556	0,0001	0,00180556
Asociality	0,00035	0,00015	0,006	0	0	0
Increased self-esteem or grandiosity	0,00017	0,0013284	0	0,0004056	0,0001	0
Increased talkativeness or pressured speech	0,00017	0,0013284	0	0,0004056	0,0001	0
Significant weight change	0,00017	0,0015684	0,0003	0,0004056	0,0001	0
Disorganized behaviour	0,00035	0,00015	0,00066	0,0004056	0	0
Delusions	0,00209995	0,0008999	0,00066	0,0023556	0,002	0,00069444
Impairment in abstraction	0,00017	0,000072	0	0,0004056	0	0
Impairment in attention	0,00017	0,0029634	0,0003	0,0004056	0,0001	0,05555555
Decreased need for sleep	0,00017	0,0013284	0	0,0004056	0,0001	0
Markedly diminished interest or pleasure in activities	0,00035	0,00362932	0,000867	0,0004056	0,0001	0,05
Depressive mood	0,00017	0,0035484	0,0003	0,0004056	0,0001	0,05396429
Euphoria, irritability, or expansiveness	0,00017	0,0021984	0	0,0004056	0,0001	0
Subjective experience of increased energy	0,00017	0,0033084	0	0,0004056	0,0001	0
Fatigue	0,00017	0,0015684	0,0003	0,0004056	0,0001	0,05555556
Flight of ideas or experience of rapid or racing thoughts	0,00017	0,0013284	0	0,0004056	0,0001	0
Increased activity	0,00017	0,0040284	0	0,0004056	0,0001	0
Reduced energy	0,00017	0,0015684	0,0003	0,0004056	0,0001	0,05555556
Grand total	**0,0085099**	**0,03381624**	**0,011967**	**0,0112008**	**0,0035**	**0,36368652**

Note: analysis of the total probability of 21-dimensional symptoms concurring in six mental disorders: Schizophrenia, Schizoaffective disorder, Schizotypal disorder, Acute and transient psychotic disorder, Delusional disorder, and Depressive disorder.