IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

SPECIAL SECTION ON NEW TRENDS IN BRAIN SIGNAL PROCESSING AND ANALYSIS

Received January 13, 2019, accepted January 21, 2019, date of publication February 13, 2019, date of current version March 20, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2899216

Automatic Detection and Diagnosis of Neurologic Diseases

LUCIANO COMIN NUNES[1], PLÁCIDO ROGÉRIO PINHEIRO[1], (Member, IEEE), MIRIAN CALÍOPE DANTAS PINHEIRO[1], MARUM SIMÃO FILHO[1], RAFAEL ESPÍNDOLA COMIN NUNES[2], AND PEDRO GABRIEL CALÍOPE DANTAS PINHEIRO[1]

[1]Graduate Program in Applied Informatics, University of Fortaleza, Fortaleza 60811-905, Brazil
[2]Federal University of Ceará, Fortaleza 60355-636, Brazil

Corresponding author: Luciano Comin Nunes (lcominn@uol.com.br)

ABSTRACT This paper presents a hybrid proposal of a specialist system with a multicriteria decision analysis method, aiming to subsidize decisions in the early diagnosis of psychological disorders. Such disorders can even cause the inability of professionals from various fields of activity, notably of those related to innovation and automation of critical business processes, which exert more pressure on results. These cited disorders cause harm to the professional, to his family, to the company for which he works, to the productive system, and to the social security of a nation. The lack of early diagnosis and the undue attention given to the symptoms only provide reactive and late measures, when the losses have already occurred, in addition to the fact that the professional shows signs of incapacity for work and social life. This paper presents a model that facilitates the process of early diagnosis of various psychological disorders from the qualitative and comparative analysis of events and criteria, using multicriteria methodology associated with a specialist system. Therefore, the proposed model constitutes a modern and consistent tool that contributes to the decision to indicate diagnoses in psychological disorders. Among the various psychological disorders described and categorized in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders of the American Psychiatric Association, this paper highlights the following: schizophrenia spectrum disorders, bipolar disorder, depressive disorders, anxiety disorders, obsessive-compulsive disorder, trauma-related disorders and stressors, dissociative disorders, and disorders related to substances and adverse disorders.

INDEX TERMS DSM-5, early diagnosis, multicriteria, psychological disorders, expert system.

I. INTRODUCTION

Although psychological disorders have specific causes and symptoms, the conventional way to establish diagnosis consists of analyzing the behavioral reactions of a human being to events in their daily lives. The manifestation of psychological disorders varies from person to person and the degree of severity. Like 'personality,' 'consciousness' and 'intelligence,' the expression 'abnormal behavior' is difficult to define due to sociocultural subjectivities intrinsic to the human being. One of the most drastic consequences for an individual suffering from psychological disorders is the lack of trust that society has in this individual. No matter how much the individual struggles to undo the negative image formed about his person, prejudices and harms are devastating and difficult to reverse. It is common in work environments that team members react with suspicion to a colleague who is suffering from a psychological disorder. One explanation for this collective behavior is the disinformation on the part of the people, beginning with the members of the individual's own family who has a psychological disorder.

Psychological disorders are among the leading causes of withdrawal from work environments, given the influence that these disorders have on the functioning of the brain as well as the immune system of people, providing them with frequent illnesses. However, some factors make a right diagnosis difficult, such as the resistance offered by a person who has a psychological disorder to accept such a situation, and a healthy person can simulate some symptoms to circumvent a situation for their benefit [1].

In order to propose a system for the early diagnosis of psychological disorders, a hybrid model will be presented

The associate editor coordinating the review of this manuscript and approving it for publication was Victor Hugo Albuquerque.

combining multicriteria decision support methodology and an expert system based on production rules and probabilities (AI). This model incorporates the main symptoms and causes of the following types of psychological disorders affecting economically active people across the world, covering various sectors and professions: Schizophrenia Spectrum Disorders; Bipolar disorder; Depressive Disorders; Anxiety Disorders; Obsessive-compulsive disorder; Trauma-Related Disorders and Stressors; Dissociative Disorders; Disorders Related to Substances and Addictive Disorders.

Thus, the importance of this study is the presentation of a model that facilitates the process of early diagnosis of various psychological disorders from the qualitative and comparative analysis of events and criteria, using multicriteria methodology associated to a specialist system. Therefore, the proposed model constitutes a modern and consistent tool that contributes to the decision to indicate diagnoses in psychological disorders.

The novelty of this study consists of a model that allows analyzing events and criteria related to several psychological disorders simultaneously, helping in the diagnosis of one or more psychological disorders, according to each clinical case under analysis. Other studies have been used in the analysis of events and criteria relating to a single psychological disorder.

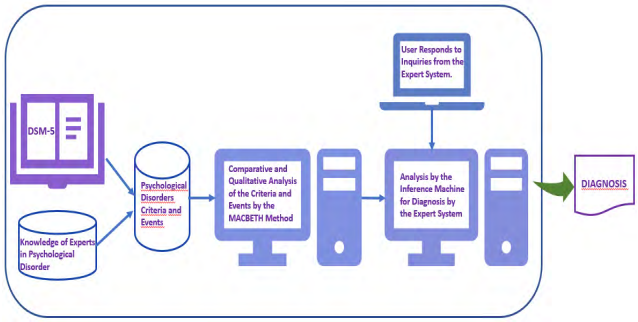


FIGURE 1. The graph with the proposed hybrid model algorithm.

The graph of Figure 1 shows the algorithm of the hybrid model proposed in this study. The MACBETH method (Measuring Attractiveness by a Categorical Based Evaluation Technique) and the Expert System cited in Figure 1 will be explained in sections four and five, respectively.

It is important to point out that hybrid models are applied in support of decision making in the health area, aiming to diagnose diseases, examples: Tamanini developed an Evaluation of the Alzheimer's Disease Clinical Stages under the Optics of Hybrid Approaches in Verbal Decision Analysis [46]. Castro developed a hybrid model to aid decision making in the neuropsychological diagnosis of Alzheimer's disease [2]. In another study, Menezes presents a proposal for a hybrid model for early diagnosis of type 2 diabetes, using decision support methods [3]. Such studies use methods and technologies like the object of this research. The difference and more significant advantage of this research to the mentioned studies lies in the fact that this work integrates AI techniques contained in a Specialist System with the MACBETH method, aiming at increasing the accuracy in indicating the best diagnostic alternatives for the psychological disorders of the study.

The present study uses the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) of the American Psychiatric Association (APA) [4], this, considering a greater organicity and better synthesis capacity of that manual.

This study has the following structure for the next sections: The second section presents the primary methods of categorization of diseases used by health professionals. The third section shows the classification of the diseases applied to the psychological disorders object of this study. The fourth section has a decision support model applied to the early diagnosis of psychological disorders. The fifth section describes an expert system applied to the diagnosis of psychological disorders and integrated with the decision support model presented in the fourth section. Finally, it presents the conclusions of this study and indicates possible future work to continue the present research in the sixth section

II. METHODS OF CLASSIFICATION OF DISEASES

A. HEALTH AND ILLNESS

According to the World Health Organization (WHO), 'health' is a state of complete physical, mental and social well-being. It is represented in an integrated way, under three domains, to know. i) Physical health - of diseases, nourished healthily, strengthened with healthy exercise practices, maintained for leisure, rest and adequate sleep time. ii) Psychological health - which consists of the formulation of clear and healthy thoughts, seeking to raise self-esteem, develop innovative ideas, provide emotional stability and tolerance to stress. iii) Social health - characterized by relationships and interpersonal skills associated with sociocultural, ethnic, socioeconomic status, educational level. Any deviation from the normal state of one of these three health domains will imply disease [5].

1) INTERNATIONAL CLASSIFICATION OF DISEASES - ICD

The Tenth Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) is the last in force of a series that began in 1893 as the Bertillon Classification or International List of Causes of Death [5]. Although the title has been amended to clarify the content and purpose of the method, the abbreviation ICD remains. The WHO presented the eleventh revision on 18/06/2018, or ICD-11. However, the entry into force of ICD-11 will be at 01/01/2022. Nowadays the ICD-10 is still in force [5]. This classification uses a multiaxial model with a structure based on three axes, namely:

- Axis I – Clinical Disorders (general and mental medicine);
- Axis II – Incapacity (for society and family);
- Axis III – Contextual factors.

The coding of the diseases has an alphanumeric formation of the type <LNNN> where:

- <L>" is an alphabetical part represented by a capital letter;
- <NNN> is the numeric part of up to three digits.

2) THE FIFTH REVISION OF THE DIAGNOSTIC AND STATISTICAL MANUAL OF MENTAL DISORDERS – DSM-5

DSM-5 is a book of reference for the American Psychiatric Association [4]. The DSM-5 was published in 2013/05/18 and describes each disorder, including typical patterns of behavior, thought and emotion, allowing the diagnosis is made sought. The first edition of the Diagnostic and Statistical Manual, known as DSM-I, was published in 1952, the second DSM-II, in 1968, and third, DSM-III (DSM-III-R), was published in 1987. The fourth edition, DSM-IV, was published in 1994 [4].

III. A CLASSIFICATION OF DISEASES APPLIED TO PSYCHOLOGICAL DISORDERS

This study presents a model of support for the early diagnosis of psychological disorders, based on the premise that it is possible to identify causes and symptoms for these disorders.

Table 1 lists forty-four control events that evidence the psychological disorders addressed in this study. Each psychological disorder has its subset of control events.

FIGURE 2. The family of psychological disorders approached in this study.

Figure 2, generated from DSM-5 of the American Psychiatric Association, presents a synthesis of the main groups of psychological disorders approached in this study.

TABLE 1. Control events of the psychological disorders in this study.

Evento	Descrição
Hallucinations	It has a perception without external stimulus.
Environment	It has a negative influence on the environment.
Evento	**Descrição**
Amnesia	The person decreases or has a loss of memory.
Anorexia	The person has an absence of appetite.
Cry	The person cries without proper motivation
Comorbidity	It has a simultaneous occurrence of disorders.
Mental confusion	Disjointed thoughts and ideas.
Acne	Small vials and sores on the skin.
Deconcentration	Inability to concentrate.
Dyspnea	Difficulty breathing.
Divorce	Affective bond break with the spouse.
Dopamine	Neurotransmitter imbalance.
Pains	It has pains without physiological causes.
Double-mindedness	Schizophrenic thoughts.
Egocentrism	The person has thought only for himself.
Stress	Results-based pressure.
Euphoria	Extreme excitement and impulsivity.
Spending frenzy	Unnecessary expenses.
Genetics	Genetic predisposition.
Hyperactivity	It hinders sleep and concentration.
Impatience	It has an agitation with abrupt actions.
Insomnia	It has a difficulty of deep sleep.
Manias	Obsessions.
Specific fears	Irrational fear of objects and situations.
Unspecific fears	Panic and fear without specification.
Loss of energy	Unexplained tiredness.
Losses	Significant losses are explainable.
Persuasion	Argue to get the desired
Pessimism	Negative thoughts.
Resignation	It has a perception of disability.
Laughs	The person smiles at random.
Seasonal	Seasonality of sunlight in winter.
Sedentary lifestyle	Lack of physical activity.
No pleasure	Lack of pleasure in life.
Serotonin	The neurotransmitter imbalance.
Solitude	Social isolation.
Sweating	It has an excess of sweat.
Suicide	The person has thoughts for self-destruction.
Tachycardia	Fast heartbeat.
Taquilalia	Speak fast and multiple words.
Tachypnea	Accelerated breathing.
Trauma	Trauma caused by events.
Sadness	Continuous and deep.
Vertigo	Dizziness.

[1], [6], [7], [8].

A. SPECTRUM OF SCHIZOPHRENIA AND OTHER PSYCHOTIC DISORDERS

SCHIZOPHRENIA

Schizophrenia is the most severe form of mental disorder. Usually, the disorder emerges in adolescence or early adulthood, and rarely after 45 [1]. According to statistics, one in every 100 people develops schizophrenia. Studies coordinated by David Astling and James Sikela have presented correlations between cognitive capacity and mental illnesses, among them schizophrenia [9]. According to these studies, individuals with schizophrenia are the price that the human species pays for the mechanism that has allowed

over time the generation of mutagenic copies of a gene known as DUF1220, retained in human evolution. According to the study, mutagenic replications of this gene provide an increase in the brain and supposedly cognitive ability. However, because the DUF1220 gene is associated with the lq21.1 region of the human genome, and because that lq21.1 region is related to mental disorders, individuals who have these mutations may be carriers of schizophrenia. These studies are in line with the popular idea that the genetic factor is one of the components that influence the onset of this disorder [10] Schizophrenia has as main characteristics [1]:

- Frequent events of delusions or bizarre thoughts that is, outside the socio-cultural context of the individual.
- Hallucinations or sensory perceptions without the presence of the being or object relative to the manifested sense, such as odors, voices, and sounds directed only to the schizophrenic individual.
- Easy laughter and crying without explanation.
- Manias of being suffering persecution.
- Disorganization of thought, making it impossible to participate in dialogues or manifestations of coherent ideas.

TABLE 2. Scale of influence of events.

0	25	50	75	100
INDIFFERENT	LITTLE INFLUENCE	MODERATE INFLUENCE	MUCH INFLUENCE	DECISIVE INFLUENCE

The scale shown in Table 2 was created from reports of specialists in psychiatry and psychology, on the degree of influence of each event in the psychological disorders object of the present study.

Figure 3 shows the main control events related to schizophrenia disorder. The numerical values that appear in Figure 3 represent the influence of the control events in the occurrence of this disorder. The higher the value, the greater the influence of the event in establishing the diagnosis for this disorder. These values constitute the application of a scale of influence of each event for the occurrence of each disorder.

B. SPECTRUM BIPOLAR DISORDER AND RELATED DISORDERS

BIPOLAR TYPE I DISORDER

The alternation between states of depression and excessive euphoria characterizes this disorder, which was known as ''manic-depressive illness'' and nowadays called ''bipolar disorder.'' The transition time from one state to another varies according to several factors not yet standardized.

Figure 4(a) illustrates these transitions: each end of the long and short axes of the ellipse represents a mood state. The horizontal axis of the ellipse represents the long transition, lasting from months to years. The vertical axis represents the short transition from hours to days. In both transitions, the disorder ends abruptly, returning the individual to the normal state and soon beginning to present behavior with characteristics opposite to the state previously experienced.

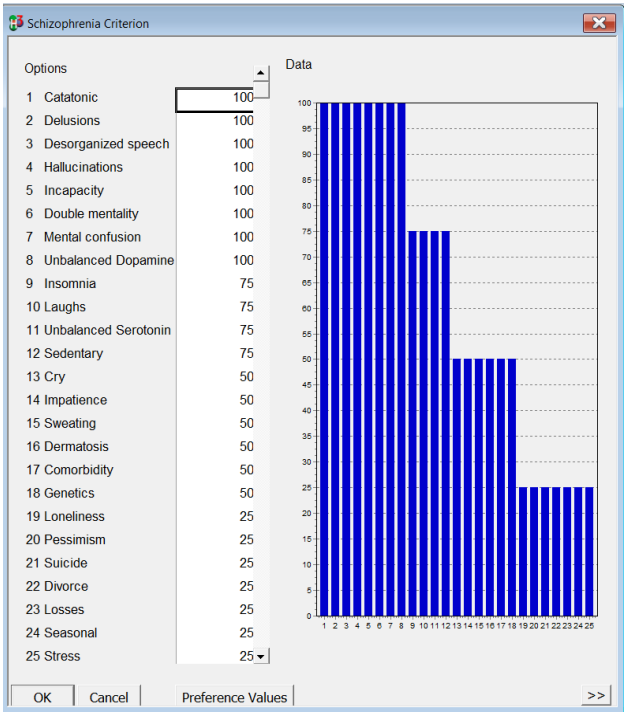


FIGURE 3. Correlated events with schizophrenia disorder.

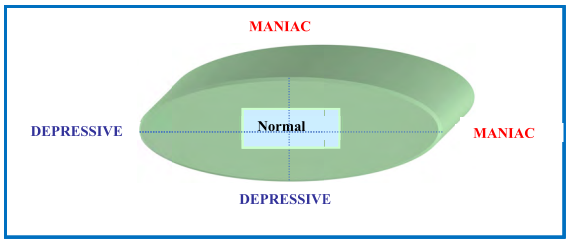


FIGURE 4. (a) Transitions from a maniac and depressive states. (b) Correlated events with bipolar type I disorder.

The risk of an individual suffering uninterruptedly from bipolar disorder throughout their lives is low, varying from 0.5% to 1.6% of the total cases diagnosed. This disorder can be classified as one of the most debilitating and lethal among psychological disorders since it has a self-destruction index (suicide) that varies from 10% to 20% of the total cases diagnosed [11], [12].

Figure 4(b) shows the main events correlated with Bipolar Type I Disorder. The numerical values shown in Figure 4 are an application of the scale presented in Table 2.

C. DEPRESSIVE DISORDERS

Also known as affective disorders or disorders related to emotion, which include misrepresentations of reality through psychotic behavior. Biological theories for these types of disorders have presented the imbalances in the rates of the neurotransmitters serotonin and dopamine as possible causative events, besides genetic aspects.

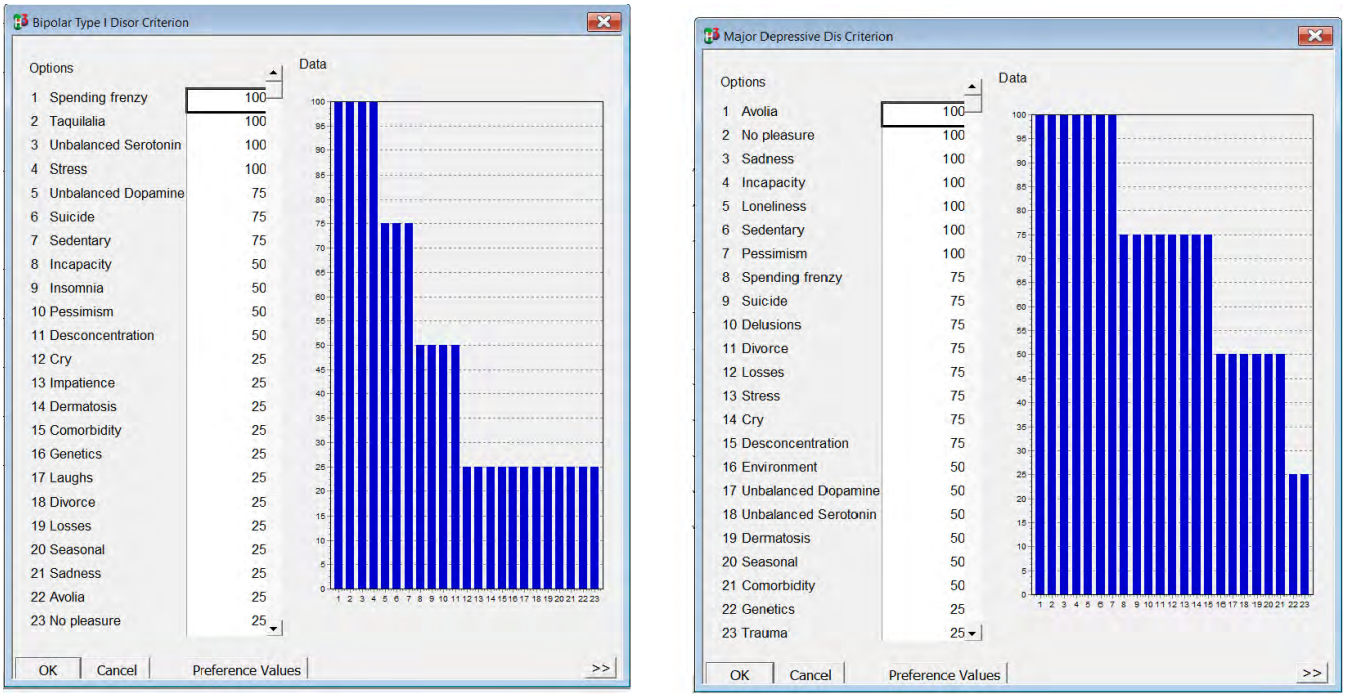


FIGURE 5. Correlated events with major depressive disorder.

Psychosocial theories emphasize interpersonal relationship problems, disorganized thinking, depreciated self-image, and the low knowledge assimilation curve [1].

MAJOR DEPRESSIVE DISORDER

Some events can lead most people to experience depressive symptoms, such as loss of a loved one, unemployment, significant financial loss. These events are healthy when they are overcome. However, some individuals suffer from depression without an apparent cause or an event that justifies such behavior. These clinically depressed individuals experience deep sadness and discouragement. They often have insomnia problems and are prone to gain weight. They feel guilty and unwilling to work, study, do personal hygiene, besides think of self-destruction and manifest dissatisfaction with losses. These feelings have no apparent cause and, when they reach a high degree of severity, the individual with depression loses contact with reality [8].

Figure 5 shows the main events correlated with major depressive disorder. The numerical values shown in Figure 5 are an application of the scale shown in Table 2.

D. ANXIETY DISORDERS

Unlike depressive disorders, anxiety disorders are characterized by an acceleration of activities. Thus, faced with situations marked by feelings of fear, apprehension, shame, harassment; there are chemical reactions in the body that increase energy levels and enable people to react to situations that threaten their physical, mental and moral integrity. It can be considered a normal process while the individual can control this level of energy. From the moment, however, in which one cannot deactivate or normalize this level of energy, leaving the person ''on'' continuously, leading to a nervous breakdown, is a problem of anxiety disorder. According to studies conducted by the American Psychiatric Association (APA), anxiety disorder is the one that most commonly afflicts the general population [4]. Statistics show that this type of disorder affects twice as many women when compared to the number of cases in men [13].

1) GENERALIZED ANXIETY DISORDER

Characterized by an extreme and constant concern that prevents the individual from relaxing and leading a normal life. The person lives with this situation for more than six months. Usually, the disorder is a consequence of an organic dysfunction that makes one focus on one's problems, without, however, solving them, and fantasizing other new problems. People with this type of disorder are afraid of something, yet they are unable to describe it. This disorder affects twice as many women as men [14], [15].

Figure 6 shows the main events correlated with generalized anxiety disorder. The numerical values shown in Figure 6 are an application of the scale shown in Table 2.

2) PANIC DISORDER

Also known as ''panic syndrome,'' this disorder is characterized by sporadic attacks that begin with an anxiety crisis.

The individual with panic becomes nervous, feels the gasping breath and an intense apprehension that lead to trembling, agitation, vertigo and accelerated heartbeat. With these

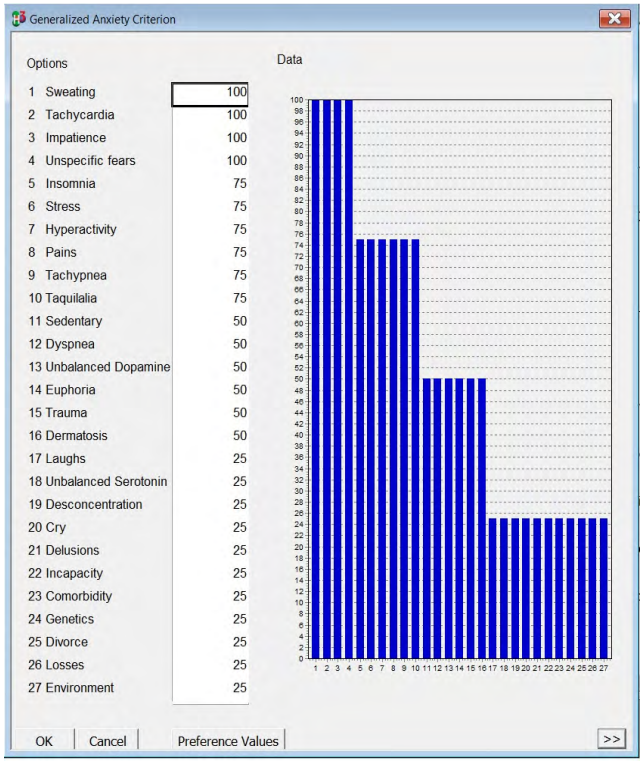


FIGURE 6. Correlated events with generalized anxiety disorder.

symptoms, he begins to imagine that he is experiencing a significant health problem, a thought that provides an even greater acceleration of nervousness that leads to new changes in the body, a kind of growing spiral. Figure 7 shows the main events correlated with panic disorder. The numerical values shown in Figure 7 are an application of the scale shown in Table 2.

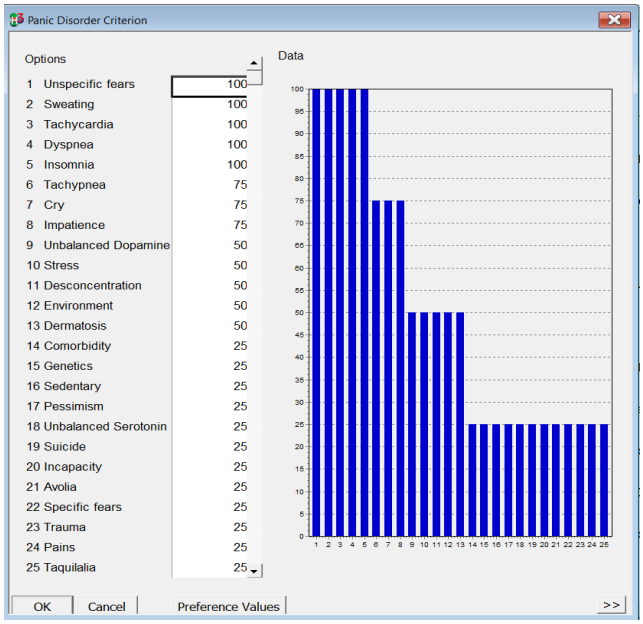


FIGURE 7. Correlated events with panic disorder.

TABLE 3. Most common types of phobias.

Phobias	A specific situation or feared object
Acrophobia	High Places
Aeroplanophobia	Travel by plane
Agoraphobia	Open Spaces
Androphobia	Men's
Claustrophobia	Small or Closed Locations
Cynophobia	Home
Electrophobia	Electricity or fear of electric shock
Social phobia	Observation or evaluation by others
Gamophobia	Marriage
Genophobia	Sex
Gynecophobia	Women
Hematophobia	Blood
Hydrophobia	Water
Misophobia	Dirt
Nictophobia	Darkness
Pyrophobia	Fire
Thanatophobia	Death
Xenophobia	Strangers
Zoophobia	Animals

3) SPECIFIC PHOBIA DISORDER

The phobias are related to unreasonably disproportionate fears of objects and situations. Although the individual is aware of the irrationality of fear, the anxiety associated with the phobia he suffers remains active in the brain, making it difficult for an attitude to bring the person back to normal.

Because the phobias are stimulated by specific objects and situations, producing intense feelings of fear, phobic disorders differ from generalized anxiety disorders and panic disorders, since the latter is triggered by something non-specific. There are more than 200 types of phobias cataloged. Table 3 shows some of the most common types of phobias.

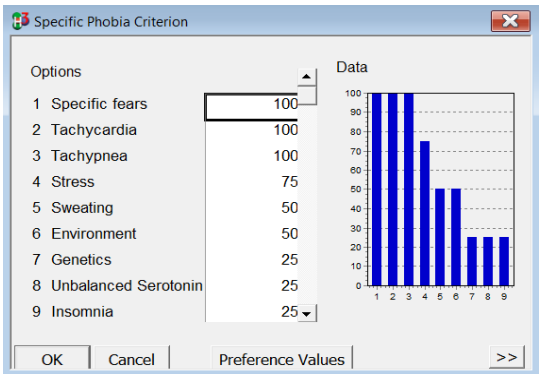


FIGURE 8. Correlated events with specific phobia disorder.

Figure 8 shows the main events correlated with specific phobia disorder. The numerical values that appear in Figure 8 constitute an application of the scale presented in Table 2.

E. OBSESSIVE-COMPULSIVE DISORDER AND RELATED DISORDERS

OBSESSIVE-COMPULSIVE DISORDER

Characterized by manias performed repeatedly, in order to consume time due to sleep, work, study, leisure, resulting in

loss of productivity and quality of life, as well as causing distress and distress to the sufferer. For those who suffer from this disorder, with every obsession that comes to mind, have to perform at least a compulsion as a form of compensation and relief for their afflictions, although temporarily, since soon again feel the same obsession that will require the realization of compulsion again. This ritual performed iteratively ends up affecting all the people who live with those who suffer from this disorder, generating conflicts and disharmonies.

Figure 9 shows the main events correlated with obsessive-compulsive disorder. The numerical values shown in Figure 9 are an application of the scale shown in Table 2.

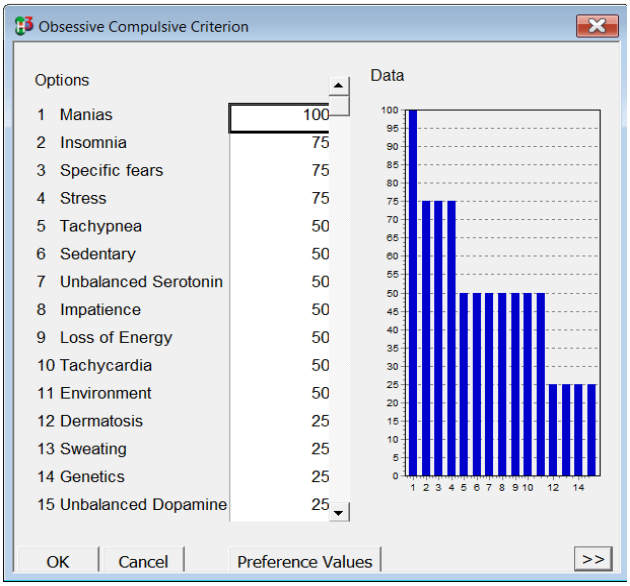


FIGURE 9. Correlated events with obsessive-compulsive disorder.

F. TRAUMA-RELATED DISORDERS AND STRESSORS

1) POSTTRAUMATIC STRESS DISORDER

This type of disorder develops after the occurrence of a traumatic event. Examples: accident, assault, rape, combat at war, moral and sexual harassment. Due to the increase in urban violence rates, this type of disorder has been reported more frequently to psychiatry and psychology professionals by workers in areas that deal with property and financial values. On the other hand, there are also reports of psychological harassment as causes of posttraumatic stress disorder due to pressures for increasing results, especially in critical areas such as information technology. Although posttraumatic stress disorder has received much attention, there is considerable controversy over its prevalence and diagnosis [16]. However, more definite information is that studies show that if victims of violence and harassment are supported psychosocially, they have minimal propensities to develop this type of disorder [17].

Figure 10 shows the main events correlated with posttraumatic stress disorder. The numerical values that appear in Figure 10 constitute an application of the scale presented in Table 2.

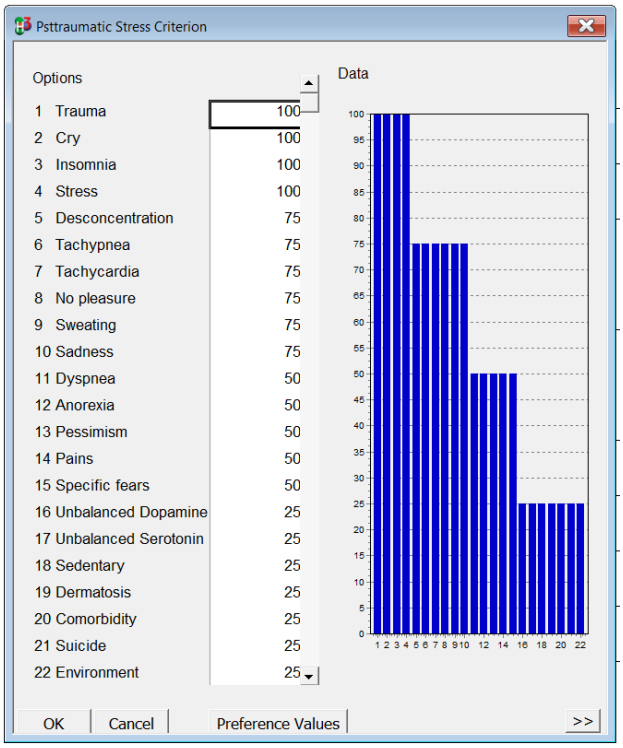


FIGURE 10. Correlated events with posttraumatic stress disorder.

G. DISSOCIATIVE DISORDERS

The individual who suffers from this type of disorder dissociates essential aspects of their consciousness and cannot identify experiences already lived, that is, develop completely different personalities. Unlike most types of psychological disorders, the causes of dissociative disorders are in environmental factors, when individuals have suffered extremely severe traumas, such as childhood sexual abuse [18], [19]. Thus, to protect oneself, the individual escapes from the traumatic situation, creating and assuming a personality wholly dissociated from the real personality.

DISSOCIATIVE IDENTITY DISORDER

Dissociative identity disorder is the most severe of dissociative disorders. In this type of disorder, the individual lives with two or more separate and distinct personalities. Each person has a unique memory, behavior, and social relationships. Stress causes the transition from one personality to another, and the individual does not remember anything about the personality previously experienced.

Figure 11 shows the main events correlated with a dissociative identity disorder. The numerical values that appear in Figure 11 constitute an application of the scale presented in Table 2

H. DISRUPTIVE DISORDERS, IMPULSE CONTROL, AND CONDUCT

1) ANTISOCIAL PERSONALITY DISORDER

People with antisocial personality usually come from homes characterized by lack of affection, cruel practices, and

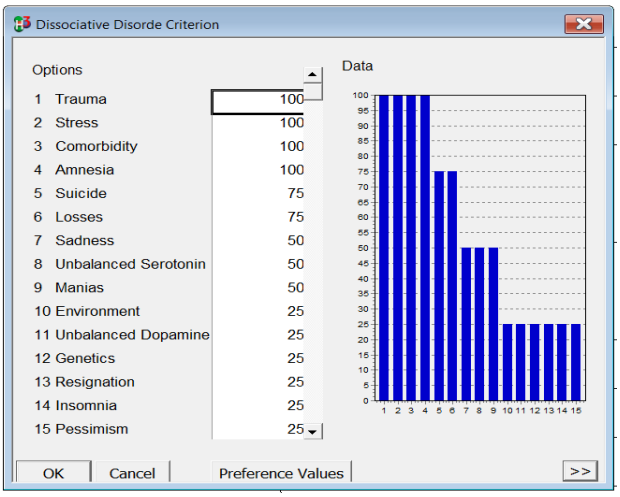


FIGURE 11. Correlated events with dissociative identity disorder.

antisocial behavior on the part of a parent. Studies show a strong interaction between heredity and the environment for this type of disorder [20]. Sociopath and psychopath are terms that describe individuals suffering from this type of disorder. Although these individuals avoid problems with the Law, they commit crimes that inflict damage to the society in which they live, as do dishonest politicians, corrupt professionals, crooked artists, unfair traders. These are social and egocentric predators, who act impulsively, unscrupulously, thinking only of their gain. Utterly devoid of ethical conscience and empathy, they take what they want and do what pleases them, violating social norms without the slightest sense of guilt or regret [21]. Studies indicate the incidence of this type of disorder in about 2,5% of the population, being 4% for the male population and 1% for the female population [22]. Evidence for biological causes comes from studies of identical twins and adopted individuals suggesting a possible genetic predisposition [23], [24]. Other studies have detected abnormal brain waves and high levels of testosterone in some people with this disorder [25], [26]. There are also pieces of evidence of environmental causes, the result of inappropriate models of creation [27].

Figure 12 shows the main events correlated with an Antisocial Personality Disorder. The numerical values shown in Figure 12 constitute an application of the scale presented in Table 2.

I. SUBSTANCE-RELATED DISORDERS AND ADVERSE DISORDERS

SUBSTANCE-RELATED DISORDER

These disorders are known as chemical dependency disorders too, encompass many types of substances and drugs. Some of these drugs are legally permitted and usually ingested, as is the case of alcoholic beverages, which are moderately consumed and only mildly modify mood and behavior. Psychological disorder arises when there are damages to the individual's social functions and occupations. In turn, the individual is considered dependent on chemical substances

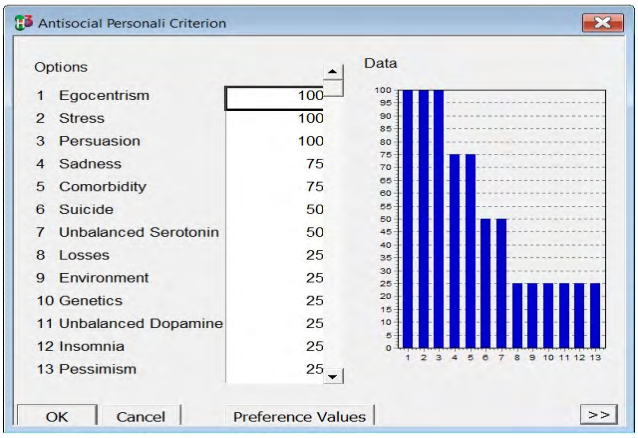


FIGURE 12. Correlated events with antisocial personality disorder.

when, in addition to impairing their social and occupational functions, the person suffers physical reactions, such as the need to consume an increasing amount to feel the same effect as the amount previously consumed, incapacitating the individual for work and social interaction.

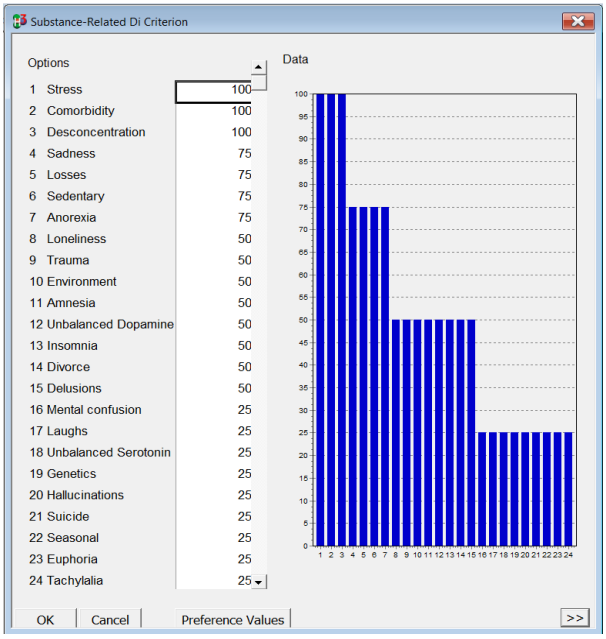


FIGURE 13. Correlated events with substance-related disorder.

Figure 13 shows the main events correlated with substance-related disorders. The numerical values shown in Figure 13 are an application of the scale presented in Table 2.

IV. A MODEL TO SUPPORT THE DECISION IN THE EARLY DIAGNOSIS OF PSYCHOLOGICAL DISORDERS

"To decide" means "to make to flow." When the decision maker decides, he/she makes flowing a process that has ceased to flow, that is, a decision made allows the process to flow again. The polymath Herbert Simon proposed the following categorization for the decision-making processes [28]:

- Structured, when based on decision support information system;
- Semi-structured, when in addition to the information system, there are the inferences and analyzes previously made by the decision maker;
- Unstructured, when the decision maker uses personal information based on common sense knowledge and experiences.

A. INFORMATION TECHNOLOGIES AS DECISION SUPPORT IN THE MENTAL HEALTH AREA

The complexity of the decision-making process in the health area is characterized by a large number of variables in each clinical case, as well as technical, genetic, cultural, social, ethical, moral, religious, economic and financial considerations. Depending on the chosen variables and the values assigned to them, the conclusions are diverse. To that end, each healthcare professional has a variety of diagnostic guides to find the best solution. According to Souza, health students generally learn about decision making in an unstructured way, which occurs through observation and reproduction of the thought processes used by their mentors [29]. According to Hunink, unlike most daily decisions, many health decisions involve uncertainties that may be related to the diagnosis, to the accuracy of the diagnostic routines, to the history of the disease, to the effects of treatment on a patient or the effects of an intervention in a population [30]. Diagnostic-based decisions affect the lives of people of all ages and all health states [31]. The present study seeks, among other aspects, to show the positive impact of the use of Information Technology (IT) in the establishment of clinical diagnoses of mental health disorders. However, critical decisions need to be made on a test basis, and despite these uncertainties, these decisions must be conclusive in order to apply therapy. In turn, the patient may want to participate in the decision to undergo therapy proposed by the health professional. However, in the field of mental disorders, this factor is difficult to control, since in some cases the patient does not have the psychological and mental autonomy to make any decision about himself. Bayegan recalls studies from the 1970s predicting that by the end of the twentieth century, computers would act as an extension of the intellect of health professionals [32]. Regarding this, currently, there are several IT solutions, such as expert systems, Web decision conference processes, image processing. All of these technologies assist health professionals in decision making, thereby confirming the Bayegan study forecast [32]. However, many challenges still need to be overcome in the search for ways to represent the broad and complex domain of health.

B. PROBLEMS OF DECISION SUPPORT AND MULTICRITERIA METHODOLOGIES

One of the most significant difficulties in arriving at a correct diagnosis in Psychology and Psychiatry is the complexity of factors that are evident, since, in addition to the high amount of information, the specialist needs to consider cultural, biological, psychosocial, information quality, symptoms common to several diseases. These aspects hinder the decision-making process as well as the model to be used since it also takes qualitative and unstructured information into account.

Multicriteria methodologies to support decision making have much to add to the diagnostic processes of Psychology and Psychiatry. In this sense, the contribution of this study aims to provide decision-makers with techniques and tools that allow them to structure and hierarchize the control events of Table 1. It also seeks to present an adequate classification of said events to assist in the formulation of a diagnosis.

C. MULTICRITERIA METHODOLOGIES

1) BASIC CONCEPTS OF MULTICRITERIA DECISION SUPPORT

Problems involving multicriteria have several acting agents, which is why their definition is merely didactic [33]. Among the concepts related to these agents acting in multicriteria decisions, the following stand out:

Decision maker - Agent that has the power and responsibility to ratify the decision, assuming the consequences for this act, whether positive or negative. The decision maker can be an individual or a group of people who sets the boundaries of the problem, specifies the goals to be achieved, and issues judgments. Not all decision-makers have the power to decide. Therefore, it is important to distinguish the degree of influence of decision-makers in the decision process [34], [35].

Analyst - An agent who interprets and quantifies the opinions of the decision makers, accomplishes the structuring of the problem, elaborates the mathematical model and presents the results to the decision. It has the duty of acting in constant dialogue and interaction with the decision makers, in the process of constant learning [33].

Model - It is a simplified representation or interpretation of reality through rules and mathematical operations that allow transforming preferences and opinions of decision makers into a quantitative result [33].

The alternative - Known as potential action. It is the object of the decision or the one that is directed to give support to the decision [36]. Identified at the beginning of the decision-making process or in the course of it and may become a solution to the problem under study [34].

Criterion - It is a criterion as being a function "g," defined in a set "A," which assigns order values of set "A," and which represents the preferences of the decision maker from a given point of view [37].

According to Vincke, when a problem has several criteria, they will be defined as "$(g_1, g_2, \ldots, g_j, \ldots, g_n)$". The evaluation of an action "a" according to criterion "j" is represented by "$g_j(a)$." The representation of the different points of view (aspects, factors, characteristics), with the help of a family $F = \{g_1, \ldots, g_j, \ldots, g_n\}$ of criteria constitutes

TABLE 4. Properties of the criteria.

Criterion	Preference Structure	Comments
True Criterion	Pre-order complete (traditional model)	Any difference implies a strict preference.
Semi-Criterion	Semi-order (threshold model)	There is a zone of constant indecision, between indifference and strict preference.
Range Criterion	Interval order (variable threshold model)	There is a zone of variable indecision along the scale, between indifference and strict preference.
Pseudo-Criterion	Pseudo-order (double threshold model)	The sudden change from indifference to the strict preference is avoided, and there is a hesitation zone, represented by the weak preference.

one of the most delicate parts in the formulation of decision problems. The criteria are classified according to the structure of preference checked, according to Table 4 [35].

Dominance Relationship - A dominance relationship occurs when two elements "a" and "b," which belong to the set "A," "a"dominate "b" "(aD b)" if, and only if:

$$g_j(a) \geq g_j(b)$$

where: $j = 1, 2, \ldots, n$ where at least one of the inequalities is of strict preference. Important to note that the dominance relationship of "a" to "b" is characterized by being a strict partial order, being an asymmetric and transitive relation. If "a" dominates "b," "a" is greater than "b" in all criteria of the problem [37].

Efficient Action - The action (or alternative) "a'' is considered efficient if, and only if, no other action of the set "A," dominates it. The efficient set of actions of "A" can be "A" itself if the dominance relation is empty, is generally considered as a set containing the interesting actions, to be analyzed in greater depth, even if there are good reasons to disregard the non-efficient ones [37].

Decision Matrix - This matrix can also be called an evaluation matrix, where each line expresses the measures of the evaluations of alternative "i'' concerning the considered "n" criteria. Each column, in turn, expresses the measures of the evaluations of the "m" alternatives concerning criterion "j." Assuming that "a_{ij}" represents the evaluation of the alternative (or action) "A_i," belonging to the set of potential actions "A," "$\lfloor a_{ij} \rfloor$" according to criterion "g_j," it is possible to build a matrix similar to that shown in Table 5 [34].

TABLE 5. Decision matrix.

Criteria→	g_1	g_2	$\cdots$	g_j	$\vdots$	g_n
Limits→	q_1, p_1	q_2, p_2	$\cdots$	q_j, p_j	$\vdots$	q_n, p_n
Alternatives↓						
A_1	a_{11}	a_{12}	$\cdots$	a_{1j}	$\vdots$	a_{1n}
A_2	a_{21}	a_{22}	$\cdots$	a_{2j}	$\vdots$	a_{2n}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\vdots$	$\cdots$
A_i	a_{i1}	a_{i2}	$\cdots$	a_{ij}	$\vdots$	a_{in}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\vdots$	$\cdots$
A_m	a_{m1}	a_{m2}	$\cdots$	a_{mj}	$\vdots$	a_{mn}

2) MULTICRITERIA DECISION SUPPORT

The MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) approach is a multicriteria decision support approach that has emerged in response to the question: How to build a range of preferences from a set of options without forcing decision makers to produce your preferences in a numerically direct way? This approach allows assigning notes to each alternative through a peer comparison. Given two alternatives, the decision maker should say which is the most attractive, in the case has a higher degree of confidence, and what is the degree of this attractiveness in a semantic scale that has correspondence with an ordinal scale. The program itself performs the analysis of cardinal coherence (transitivity) and semantics (relations between differences), suggesting, in case of incoherence, how to solve it. By linear programming, a scale of notes is suggested and the intervals at which they can vary without making the problem inconsistent. It is also possible for the decision maker to graphically adjust the value of the assigned scores, within the allowed intervals [38]. According to Souza, in the MACBETH method, when the decision maker is asked to make value judgments about the alternative in each situation, he will do so regarding the attractiveness he feels for this alternative [39]. This task is defined by the construction of a criterion function v_j, such that:

- For $a, b \in A$, $v(a) > v(b)$, if and only if, for the evaluator, a is more attractive (locally) than b (aP b);
- Any positive difference, $v(a) > v(b)$, numerically represents the value difference between a and b, with "aP b'' always regarding a fundamental point of view j(PVFj) or criterion j. Then, for each $a, b, c, d \in A$, with a being more attractive than b and c being more attractive than d, we see that $v(a) - v(b) > v(c) - v(d)$, if and only if, "the difference in attractiveness between a and b is greater than the difference in attractiveness between c and d".

The fundamental question of the MACBETH method is: "Given the impacts $ij(a)$ and $ij(b)$ of two potential actions a and b, from a fundamental point of view PVFj, being judged more attractive than b, the difference in attractiveness between a and b is judged to be "*null*," "*very weak*," "*weak*," "*moderate*," "*strong*," "*very strong*," or "*extreme*." It is

introduced a semantic scale formed by categories of attractiveness difference, not necessarily the same size, in order to facilitate the interaction between the decision maker and the analyst. The semantic categories, C_k, $k = (1, \ldots, 6)$, are represented as follows: [40]

- C_1 very weak attractiveness difference (or between null and weak) $\rightarrow C_1 = [s_1, s_2]$ and $s_1 = 0$
- C_2 difference of weak attractiveness $\rightarrow C_2 =]s_2, s_3]$
- C_3 difference in attractiveness moderate (or between weak and strong) $\rightarrow C_3 =]s_3, s_4]$
- C_4 difference in strong attractiveness $\rightarrow C_4 =]s_4, s_5]$
- C_5 difference in attractiveness very strong (or between strong and extreme) $\rightarrow C_5 =]s_5, s_6]$
- C_6 difference in extreme attractiveness $\rightarrow C_6 =]s_6, +[$

The decision maker should choose any of the seven semantic categories, or any sequence from "*very weak*" to "*extreme*" (e.g., "*very weak* to *very strong*," or "*weak* to *moderate*"). Since "*null*" represents equal attractiveness, "*null*" cannot be combined with any of the other six categories of attractiveness difference. This scale needs to satisfy the following rules [41]:

- For all $x, y \in S$, and $S = v(x) > v(y)$, if and only if x is more attractive than y;
- For all $k, k' \in \{0,1,2,3,4,5,6\}$ with $k \neq k'$, for all $x, y \in C_k$ and for all $w, z \in C'_{k'} = v(x) - v(y) > v(w) - v(z)$, if and only if $k > k'$, where x, y, w and $z =$ potential actions; $S =$ set of viable potential actions; $v(x) =$ attractiveness of the action x; $k, k' =$ numbers associated with the semantic categories of the MACBETH method; C_k, $C'_{k'} =$ semantic categories of the MACBETH method. Maintaining the consistency of all value judgments is not easy, but the MACBETH method provides when identifying inconsistencies, suggestions that can be accepted by the decision maker. If, on the one hand, this method introduces a range of the real line associated with each of the categories, on the other hand, this interval is not fixed a priori, being determined simultaneously with the numerical scale of value "v" that is being sought.

The construction of value judgments matrices is useful to facilitate the expression of the absolute judgments of attractiveness difference between the pairs of alternatives. In cases where the matrices of value judgments are substantial, inconsistencies in the value judgments of the decision maker are common. There are two types of inconsistencies: semantics, where the assignment of attractiveness difference category to a pair of alternatives is not logically acceptable, and cardinal, if the representation of judgments is not possible through a cardinal scale within the real numbers [42].

3) APPLICATION OF MACBETH METHOD

The present study had the application of the MACBETH method because it is a method that specialized in the use of hierarchization of the importance of multicriteria component events, typical of the area of human health. This method was applied in determining the attractiveness of psychological disturbance control events, in order to simplify the qualitative judgment of the decision-maker, since the whole set of alternatives need not be evaluated simultaneously. However, it is notorious for the decision-maker to remain coherent as the number of alternatives and criteria increases. Thus, the method makes the analysis of the cardinal and semantic coherence and still suggests, when necessary, the shape of the contour. To facilitate the handling of the concepts of the MACBETH method, the Hiview Software was used which has, among its functionalities, the option that executes and implements MACBETH. Hiview was the application chosen for the generation of the trial's matrices, to perform various sensitivity and robustness analyzes of the model results, offering numerous graphical representations that facilitate the elaboration of a report justifying the elaborated recommendations. Based on the MACBETH approach, this tool is of fundamental importance for evaluating the models based on this method [43]. This application executes in its functionalities the software M-MACBETH with the objective of verifying the consistency of the information and the potential of the methodology used. It analyzes the trend of the local and global results of actions when the substitution rates are varied [44]. The Hiview tool provides decision makers with confirmation of their judgments or allow changes in values that are not in line with their expectations, validating the data model and consolidating its credibility.

4) APPLICATION OF CONTROL EVENTS TO THE DECISION SUPPORT METHODOLOGY

As shown in the introduction section, the algorithm in Figure 1 shows that the control events and criteria described in Table 1 are the input parameters for the Hiview tool that runs M-Macbeth. This tool compares, for each psychological disorder, the respective reference alternatives, from the most important to the least important. An example can be seen in Figure 14. The results generated by M-Macbeth are parameters for the Expert System, which also receives as parameter the answers given by the user of the expert system for each presented clinical question. After that, in its final processing phase, the proposed model presents the diagnosis.

Figure 14 shows the degrees of the attractiveness of a control events subset of Table 1, analyzed from the perspective of Antisocial Personality Disorder. This control events subset is submitted to the decision support methodology implemented in this study through the Hiview tool, which also performs the MACBETH method. Thus, the degrees of attractiveness between control events form the "Current Scale" of confidence factors, indicating whether there is qualitative consistency in this comparison, by pairs, i.e., whether there are "Consistent Judgments." It is important to emphasize that each Psychological Disorder has its subset of control events, which will be submitted to this methodology.

Regarding the confidence factors, Figure 15 shows how the decision maker can adjust these degrees of attractiveness among the control events, pointing in a ruler the limits

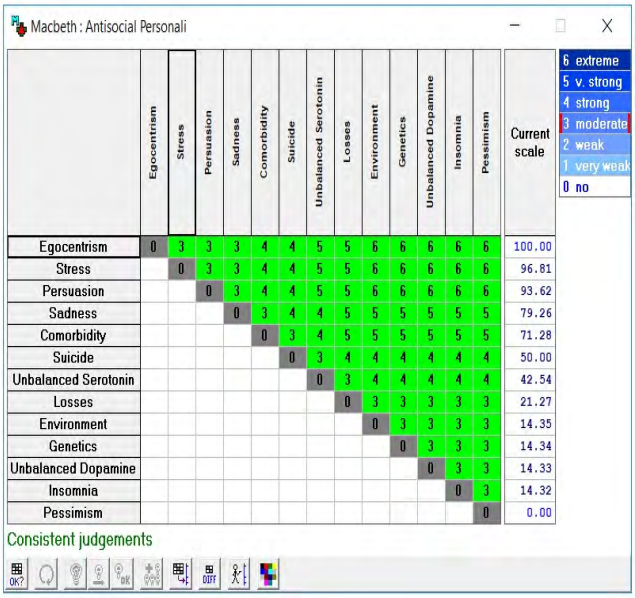


FIGURE 14. The matrix of value judgment and difference in attractiveness between control events in Antisocial Personality Disorder.

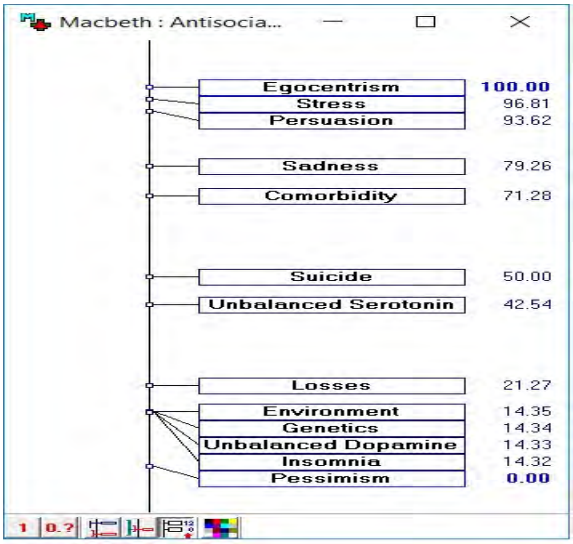


FIGURE 15. Control events with new confidence factors within allowable intervals.

between the different degrees of the attractiveness of these events. If the decision maker modifies these values, the new degrees of attractiveness indicated in the rule are reflected in the current scale of the matrix, as well as adjustments in the confidence factors of the control events.

The model presented in this study proposes that the control events and respective confidence factors, such as those listed in Figure 14, be exported to the ExpertSINTA tool, described in section V, aiming at the composition of the knowledge base of the Expert System for diagnosis of the Psychological Disorders object of this research. That is, each disorder will have a value-judgment matrix generated from their respective control events and confidence factors. These control events and confidence factors will feed the knowledge base of the Expert System described in section V. It is worth mentioning that the export of control events and confidence factors will be done through the collection of answers to queries correlated with each control event. That is, the control events and confidence factors, submitted to the MACBETH method, will guide the values of the variables defined in the Expert System described in section V. These variables are categorized in "common-variables" and "objective-variables." The "common-variables" correspond to the symptoms and causes of the disorders studied. In turn, the "objective-variables" correspond to the diagnosis for the psychological disorder investigated.

On the other hand, according to the analysis of the psychological disorders object of the present study, each control event has a percentage of influence concerning each disorder itself and relation to the other control events. This percentage, derived from the scale of influence described in Table 1, will form the degree of confidence in the Expert System to identify the event of control and indication of the diagnosis. Thus, for each set of responses provided by the user, the Expert System makes an association to a diagnosis. Additionally, in Figures 16 and 17, the differences in attractiveness and

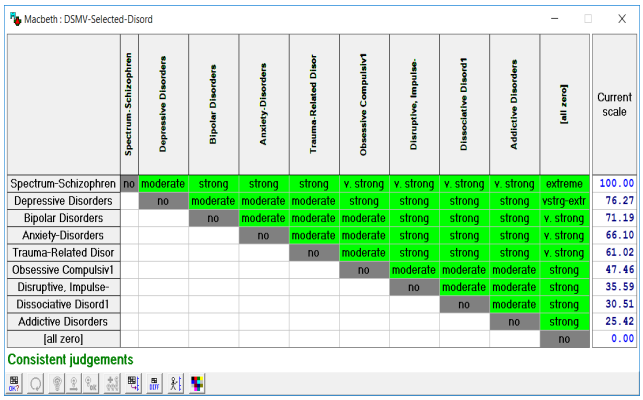


FIGURE 16. The matrix of value judgment with the difference in attractiveness among groups of disorders of this study.

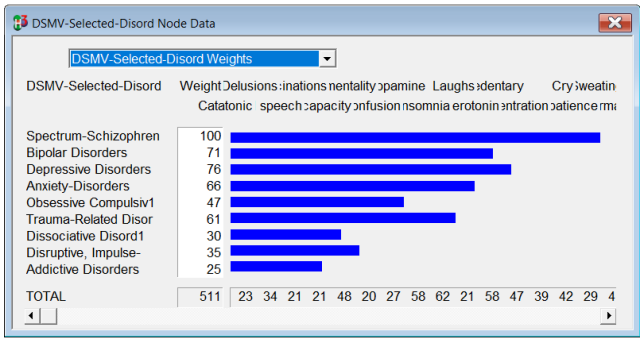


FIGURE 17. The weight of each disorder group with the others in this study.

weights of each disorder group are presented about the other groups studied.

Figures 16 and 17 make it possible to infer that ''Schizophrenia Spectrum Disorders'' have an outstanding attractiveness to other types of psychological disorders, which is why schizophrenic disorders have a greater weight concerning the other disorders. In the descending sequence of values on the ''current scale'' as well as on the ''weight scale'' is ''Depressive Disorders'' followed by ''Bipolar Disorders,'' ''Anxiety Disorders'', ''Obsessive Compulsive Disorders,'' ''Disorders Related to Trauma,'' ''Dissociative Disorders,'' ''Disruptive Disorders,'' and ''Addiction and Substance Dependence Disorders.''

V. AN EXPERT SYSTEM APPLIED TO THE DIAGNOSIS OF PSYCHOLOGICAL DISORDERS

A. CONTEXTUALIZATION OF AN EXPERT SYSTEM

Expert Systems are associated with the expression of Artificial Intelligence (AI) and are useful in generating knowledge, which is why they can assist in the decision-making process. Two are the research strands for the construction of expert systems: ''the connectionist'' and ''the symbolic.'' ''The connectionist'' aims at the modeling of human intelligence through the simulation of neurons and their respective synapses. This proposal was formalized initially in 1943 when the neuropsychologist McCulloch and the logical Pitts proposed a first mathematical model for a neuron. In turn, ''the symbolic'' slope followed the logical tradition and had in McCarthy and Newell its principal investigators. Thus, expert systems are built with rules that replicate the knowledge of experts in branches of human knowledge and aim to solve certain problems in specific domains.

The mobility of IT resources enables the portability of expert systems, making them more attractive and popularly more accessible. Providing tools of this type, to support decision making, goes beyond providing graphs and tables to the user. These resources mean presenting them with a ''North'' in identifying their needs, simulating scenarios and enabling speed and quality in the solutions to their problems. The most common architecture of expert systems involves production rules structured simply in a set of conditions in style ''*IF* ... *THEN* ...'' with the possibility of including logical connectives relating the attributes in the scope of knowledge and the use of probability. In general, systems with automated reasoning can be used by incorporating internal and external databases into the organization. These systems can also be incorporated into the set of tools available in the databases.

B. GENERATOR OF EXPERT SYSTEMS

The ExpertSINTA is a computational tool that applies Artificial Intelligence techniques for automatic generation of expert systems, using a knowledge representation model based on production rules and probabilities. This tool has a shared inference machine, which enables the automatic construction of menus, screens, and the probabilistic treatment of production rules. The user responds to a sequence of questions presented by the expert system, which, after inferences, fits the answers in the context pointed out by the user [45]. The expert systems generated in ExpertSINTA follow the architecture outlined in Figure 18.

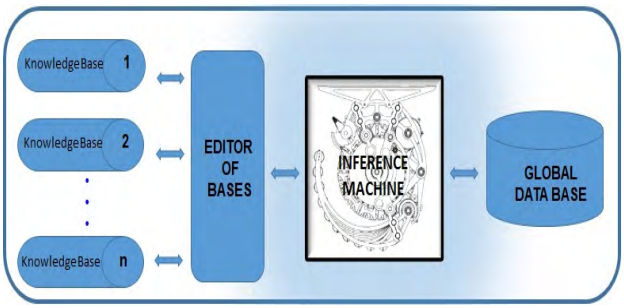


FIGURE 18. ExpertSINTA simplified architecture.

Subtitle:

Knowledge Base – composes the information representative of the facts and the rules that the specialist uses. It is represented computationally.

Editor of Bases – is the means by which the shell allows the implementation of the desired knowledge bases.

Inference Machine – this is the part of the specialist system responsible for the logical deductions on the knowledge base.

Global Data Base – Consists of the evidence pointed out by the user of the expert system during a consultation.

The control events with their respective confidence factors, referring to the Psychological Disorders of this study, are summarized in section II. After this, they are analyzed and confronted in pairs in section III, generating the values of the differences of attractiveness necessary to the judgment of the value matrix generated by the MACBETH method, as exemplified in Figures 14 and 15. After this, the information of each subset of control events indirectly feeds ExpertSINTA aiming at the construction of the Expert System. Figures 19 to 28 present the steps for the construction of the Specialist System, which will aid in diagnosis that points to the possibility of the individual suffering or not suffering from psychological disorders.

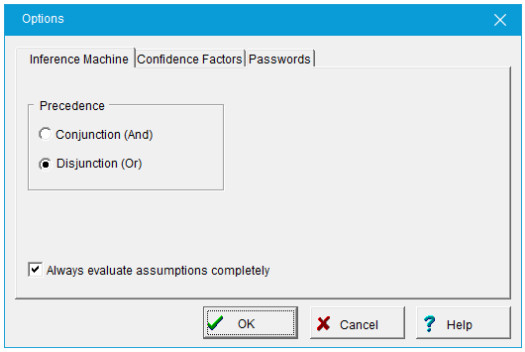


FIGURE 19. Precedence of logical operators.

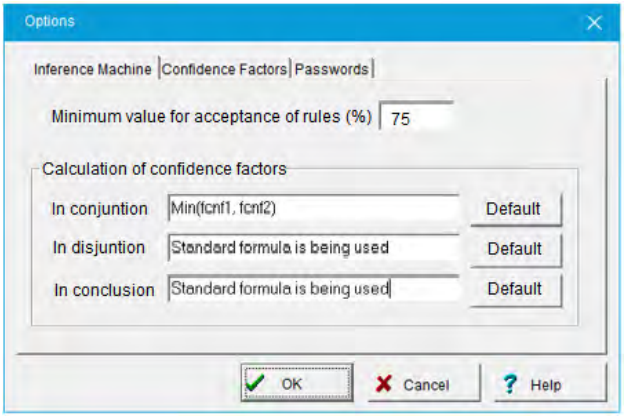


FIGURE 20. Preset of the confidence factors.

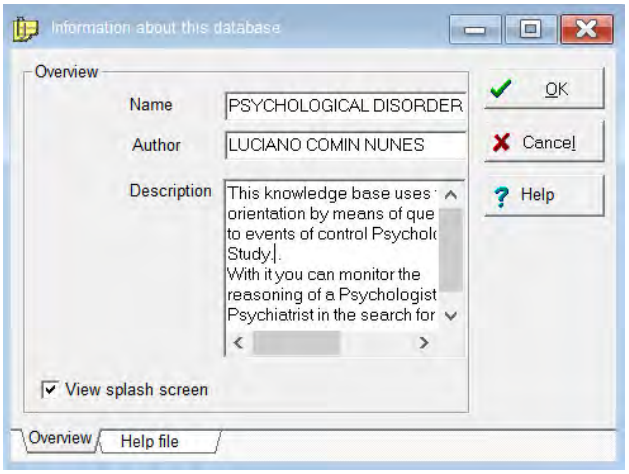


FIGURE 21. General Information on the Expert System.

FIGURE 22. Definition of variables in ExpertSINTA.

Figure 19 illustrates of how the ExpertSINTA user should proceed by defining the precedence of the logical operators that will be used by the Inference Machine, i.e., whether (A and B) or C / A and (B or C).

Figure 20 shows the alter of the minimum value for the confidence factor. The user can set the minimum value for a rule to be accepted, informing the minimum parameter that can be, in percentage terms, any natural number from 0 to 100. The ExpertSINTA uses some functions to calculate confidence factors for specific events. These events can be a conjunction, a disjunction, or an accepted rule. Each function has two implicit parameters, *fcnf1* and *fcnf2*, which correspond respectively to the degree of confidence in the first term of the conjunction and the degree of trust of the second term of the conjunction. For example, change the function of the conjunction to the minimum between the two values (press the <Default> button if the standard formula is in use) next to the conjunction function and type *Min (fcnf1, fcnf2)*. In addition to this, it is possible to place a password for the database that will be created. This option is most commonly used when the expert knowledge base is stealthy.

Figure 21 presents general information about the knowledge base that will be built. This window will appear as soon as the user starts using the expert system.

Figure 22 illustrates the definition of variables in ExpertSINTA, which will make up the knowledge base of the expert system. For each control event described in Table 1, a corresponding variable will be created.

Figure 23 shows how the target variables are defined, that is, those that indicate the diagnoses presented as a result of the expert system.

Figure 24 illustrates how the issues that will be presented to the user of the expert system are defined, i.e., the expert system interface is defined here. Also, at this time it is indicated if together with the response the user must inform the confidence factor.

Expert Systems work with logical rules. The ExpertSINTA allows each logical rule to be inserted into the user preference order. Figure 25 shows an example of a list of logical rules constructed from the ExpertSINTA, rule editor.

The rule editor that will constitute the reasoning logic of the expert system can be visualized in Figure 26. Mentioned rules lead the system user to a diagnosis. Note that the rules follow the structure "*IF*... *THEN*...".

During the execution of the expert system, the user can interact through graphical interfaces as shown in Figure 27.

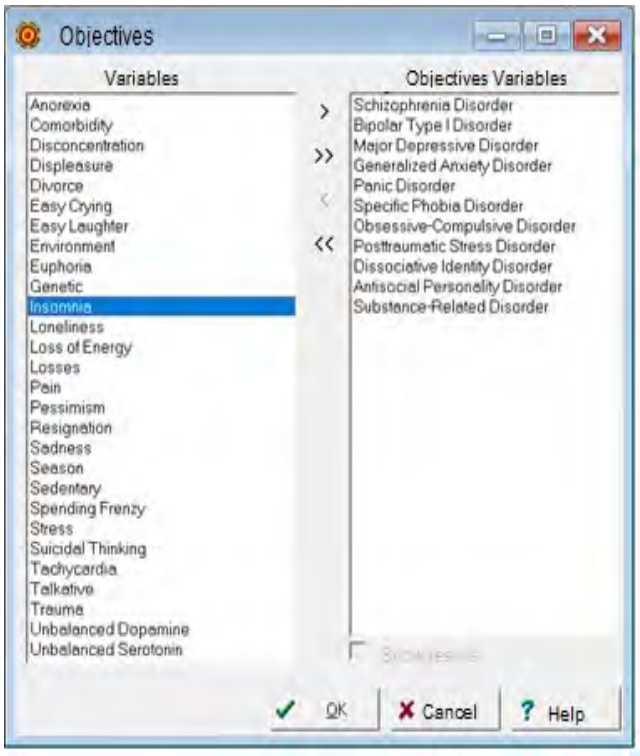


FIGURE 23. Definition of objectives variables.

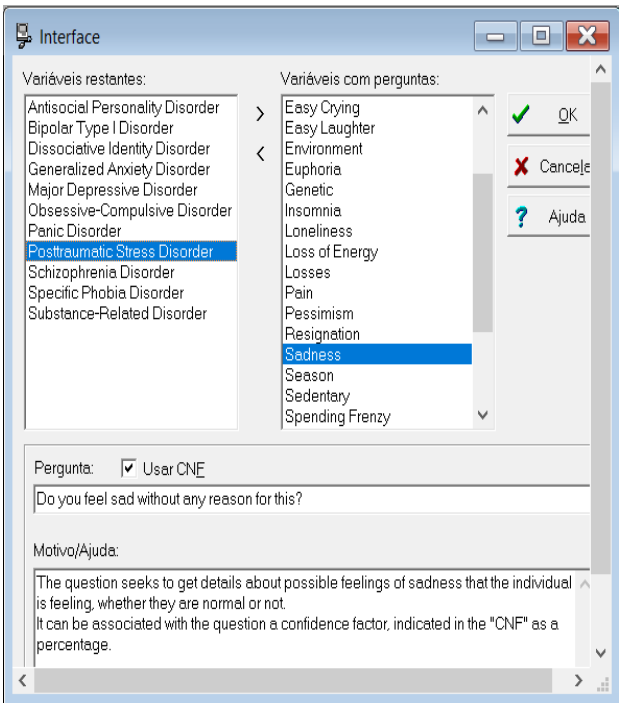


FIGURE 24. Creating user interfaces.

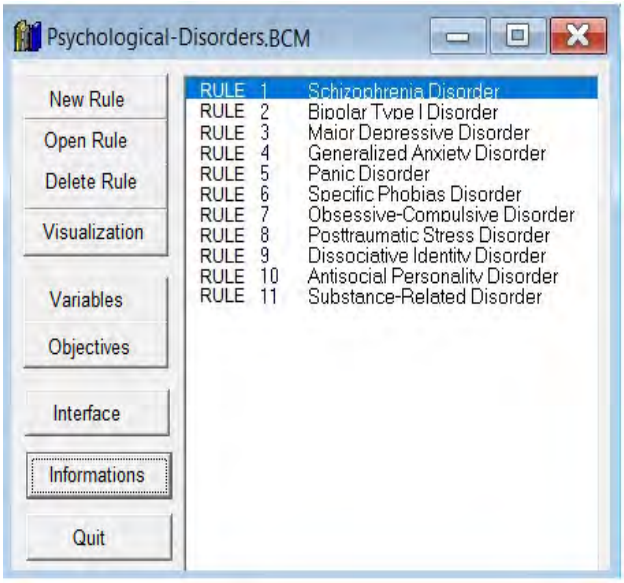


FIGURE 25. Creating logical rules.

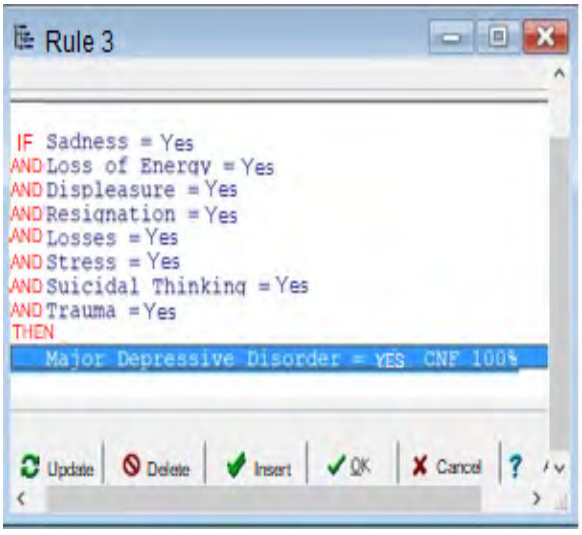


FIGURE 26. Defining logical rules.

FIGURE 27. Data entry by the user interface.

The interaction through these interfaces enables the collection of values that feed the variables and confidence factors used in the expert system.

The ExpertSINTA provides, for each expert system, a search tree that constitutes a trail of logical reasoning conducted by the specialist. Figure 28 provides a view of this

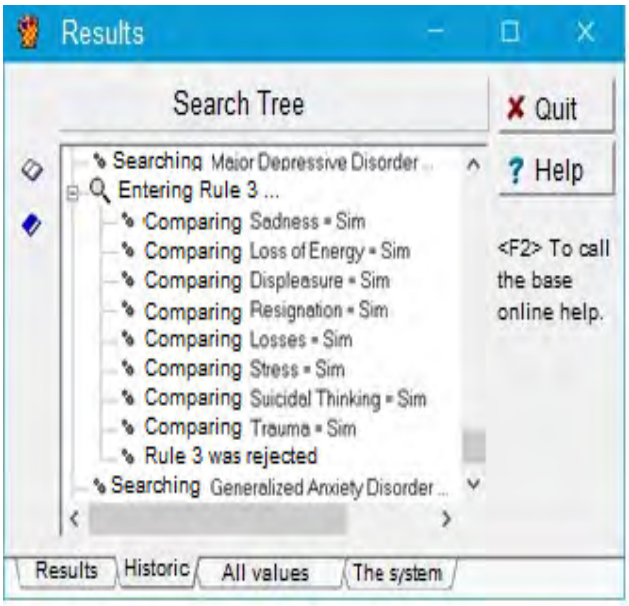


FIGURE 28. Track to aid in the analysis of results after diagnosis.

trail, which assists in the analysis of the results after obtaining the diagnosis.

C. LITERATURE REVIEW AND CONTINUOUS IMPROVEMENT

Through a systematic mapping, a secondary study can be carried out to identify gaps in the current literature on the topic addressed in the present study.

VI. CONCLUSION AND FUTURE WORK

Despite the technological advances much still needs to be done for the automation of decision-making processes, especially when the multicriteria analysis is involved.

In the present study, it was possible to observe that the information generated in the analysis of the multicriteria methodology was used in the algorithm with the objective of transforming them into variables with the respective confidence levels, which were processed by the machine of inference of the expert system through the use of "*IF... THEN...*" rules, with the purpose of using this information to point the diagnosis, incorporating it into its knowledge base.

The automation of this process of transition between the multicriteria methodology and the expert system is a challenge that remains to be solved through the construction of a bridge that allows this integration. Unfortunately, such a task was not possible within the scope of this work, given the limitations of time resources and the availability of technical staff.

Thus, the test performed in the present work tried to show a hybrid model, using a connection manually. Therefore, it was tried to present the viability of the integration among the mentioned technologies: a multicriteria methodology to support decision-making and the expert system generated by ExpertSINTA. With this proposal, it is hoped to have contributed to the quality of the automated diagnosis.

Finally, it was noticed that this field of work is still very little explored, and it is up to the entities linked to the research, to encourage, in order to have more concrete results, since organizations have needed solutions based on expert systems.

It is suggested, therefore, to improve the model proposed in this work, the adoption of the following measures:

- An improved user interface of the Expert System including, among its functions, the export and import of data files containing control events and degrees of confidence.
- Formatting and automation of generic questionnaires covering control events and degrees of confidence.
- Use of some other multicriteria methodologies, such as influence diagram and Bayesian networks.

ACKNOWLEDGEMENT

The authors would like to thank the National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES) and Foundation of Support to the Scientific and Technological Development of the State of Ceara (FUNCAP) for the support received on this project.

REFERENCES

[1] K. Huffman, M. W. Vernoy, and J. Vernoy, *Psychology in Action*, Hoboken, NJ, USA: Wiley, 2000, ch. 14.
[2] A. K. A. de Castro, P. R. Pinheiro, M. C. D. Pinheiro, "A hybrid model for aiding in decision making for the neuropsychological diagnosis of Alzheimer's disease," in *Lecture Notes in Computer Science* (Rough Sets and Current Trends in Computing), vol. 5306, 2008, pp. 495–504.
[3] A. C. Menezes, P. R. Pinheiro, M. C. D. Pinheiro, and T. P. Cavalcante, "Towards the applied hybrid model in decision making: Support the early diagnosis of type 2 diabetes," in *Proc. 3rd Int. Conf. Inf. Comput. Appl. (ICICA)* LNCS, vol. 7473, 2012, pp. 648–655.
[4] *APA—American Psychiatric Association*. Access: Sep. 1, 2019. [Online]. Available: http://psych.org/MainMenu/Research/DSMIV/FAQs.aspx
[5] *WHO—World Health Organization*. Access: Sep. 1, 2019. [Online]. Available: https://www.who.int/classifications/icd/icdonlineversions/en/
[6] R. O. Straub, *Health Psychology*. Dearborn, MI, USA: Worth Publishers, 2002.
[7] M. C. Abreu, *Depression and Maturity*, Brasília - Ed. Plano, TX, USA, 2003, p. 160.
[8] C. B. Pontes, *Secrets of the Depression*. Fortaleza, Brazil: Fundação Demócrito Rocha, 2000, p. 128.
[9] D. P. Astling, I. E. Heft, K. L. Jones, and J. M. Sikela, "High resolution measurement of DUF1220 domain copy number from whole genome sequence data, *Bio. Med. Central Genomics*, vol. 18, p. 614, Aug. 2017. doi: 10.1186/s12864-017-3976-z.
[10] A. Fortna *et al.*, "Lineage-specific gene duplication and loss in human and great ape evolution," *PLoS Biol.*, vol. 2, no. 7, p. e207, Jul. 2004.
[11] D. F. MacKinnon, K. R. Jamison, and J. R. DePaulo, "Genetics of Manic-depressive Illness," *Annu. Rev. Neurosci.*, vol. 20, pp. 355–373, 1997.
[12] F. K. Goodwin and S. N. Ghaemi, "Understanding manic-depressive illness," *Arch. General Psychiatry*, vol. 1, pp. 23–25, Jan. 1998.
[13] P. M. Lewinsohn, I. H. Gotlib, M. Lewinsohn, J. R. Seeley, and N. B. Allen, "Gender differences in anxiety disorders and anxiety symptoms in adolescents," *J. Abnormal Psychol.*, vol. 107, no. 1, pp. 109–117, 1998.
[14] O. Brawman-Mintzer and R. B. Lydiard, "Biological basis of generalized anxiety disorder," *J. Clinical Psychiatry*, vol. 58, pp. 16–25, Jan. 1997.
[15] O. Brawman-Mintzer and R. B. Lydiard, "Generalized anxiety disorder: Issues in epidemiology," *J. Clinical Psychiatry*, vol. 57, no. 7, pp. 3–8, 1996.

[16] T. M. Keane, K. L. Taylor, and W. E. Penk, "Differentiating post-traumatic stress disorder (PTSD) from major depression (MDD) and generalized anxiety disorder (GAD)," *J. Anxiety Disorders*, vol. 11, no. 3, pp. 317–328, 1997.
[17] E. M. Carroll, D. B. Rueger, D. W. Foy, and C. P. Donahoe, "Vietnam combat veterans with posttraumatic stress disorder: Analysis of marital and cohabitating adjustment," *J. Abnormal Psychol.*, vol. 94, no. 3, pp. 329–337, 1985.
[18] L. M. Dickinson, F. V. DeGruy, III, W. P. Dickinson, and L. M. Candib, "Health-related quality of life and symptom profiles of female survivors of sexual abuse," *Arch. Family Med.*, vol. 8, pp. 35–43, Jan. 1999.
[19] D. O. Lewis, C. A. Yeager, Y. Swica, J. H. Pincus, and M. Lewis, "Objective documentation of child abuse and dissociation in 12 murderers with dissociative identity disorder," *Amer. J. Psychiatry*, vol. 154, no. 12, pp. 1703–1710, 1997.
[20] J. PARIS, "Does childhood trauma cause personality disorders in adults?" *Can. J. Psychiatry, 43*, pp. 148–153, 1998.
[21] R. D. Hare, "*Without Conscience: The Disturbing World of the Psychopaths Among Us*. New York, NY, USA: Pocket Books, 1993.
[22] R. D. Hare, "Psychopaths: New trends in research," *Harvard Mental Health Lett.*, vol. 12, no. 3, pp. 4–5, 1995.
[23] G. R. Bock and J. A. Goode, *Genetics of Criminal and Antisocial Behaviour*. Chichester, England: Wiley, 1996.
[24] W. W. Hartup and C. F. M. Van Lieshout, *Personality Development in Social Context*, 1995.
[25] A. S. Aromäki, R. E. Lindman, and C. J. P. Eriksson, "Testosterone, aggressiveness, and antisocial personality," *Aggressive Behav.*, vol. 25, no. 2, pp. 113–123, 1999.
[26] J. Volavka, "Aggression, electroencephalography, and evoked potentials: A critical review," *Neuropsychiatry, Neuropsychol., Behav. Neurol.*, vol. 3, no. 4, pp. 249–259, 1990.
[27] L. Sperry, *Handbook of Diagnosis and Treatment of the Personality Disorders*. New York, NY, USA: Brunner/Mazel, 1995.
[28] H. A. Simon, *Administrative Behavior: A Study of Decision Making Processes in Administrative Organization*, 4th ed. New York, NY, USA: The Free Press, 1997.
[29] F. M. C. Souza, *Rational Decisions in Situations of Uncertainty*, 1st Ed. Recife, Brazil: University Editor of the Federal University of Pernambuco, 2002.
[30] M. G. M. Hunink, *Decision Making in Health and Medicine: Integrating Evidence and Values*. Cambridge, U.K.: Cambridge Univ. Press, 2001.
[31] O. I. Reznik, *The Secrets of Medical Decision Making: How to Avoid Becoming A Victim of the Health Care Machine*. Ann Arbor, MI, USA: Loving Healing Press, 2006.
[32] E. Bayegan, "Knowledge representation for relevance ranking of patient-record contents in primary-care situations," NTNU Tech. Rep. 144, IDI Rep. 14, 2002, p. 203.
[33] J. C. C. B. S. D. Mello, E. G. Gomes, F. R. Leta, and R. B. V. Pessolani, "Basic concepts of multicriteria decision support and its application in the project aero design," *Engevista*, vol. 5, no. 8, pp. 22–35, 2003.
[34] L. F. A. M. Gomes, C. F. S. Gomes, and A. T. Almeida, *Management Decision Making: Multicriteria Approach*, 2nd ed. São Paulo, Brazil: Atlas, 2006.
[35] D. C. Morais, "Multicriteria grouping for strategic planning of loss control in water supply," Ph.D. dissertation, Federal University of Pernambuco, Recife, Brazil, 2006, p. 148.
[36] J. É. Figueira, S. Greco, and M. Ehrogott, "Multiple criteria decision analysis: State of the art surveys," *Int. Ser. Oper. Res. Manage. Sci.*, vol. 78, pp. 3–24, 2005.
[37] P. Vincke, *Multicriteria Decision-Aid*. Hoboken, NJ, USA: Wiley, 1992.
[38] C. A. B. E. Costa, and D. Corte, "JM; VANSNICK, JC MACBETH," LSE-OR Work. Paper 56, 2003.
[39] G. G. C. de Souza, "A Multicriteria Model to Produce a Journal," Ph.D. dissertation, Univ. Fortaleza, 2003.
[40] C. A. B. E. Costa, J. C. Lourenço, M. P. Chagas, J. C. B. E. Costa, "Development of reusable bid evaluation models for the Portuguese Electric Transmission Company," *Decis. Anal.*, vol. 5, no. 1, pp. 22–42, 2008.
[41] C. A. B. E. Costa, J. M. De Corte, and J. C. Vansnick, "On the mathematical foundations of MACBETH," in *Multiple Criteria Decision Analysis* (International Series in Operations Research & Management Science), S. Greco, M. Ehrgott, and J. Figueira, Eds. 2005, pp. 410–442.
[42] C. A. B. E. Costa and M. P. Chagas, "A career choice problem: An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments," *Eur. J. Oper. Res.*, vol. 153, pp. 323–331, Mar. 2004.
[43] C. A. B. E. Costa, J. M. D. Corte, and J. C. Vansnick, *M-MACBETH*, Versão User manual, 2005.
[44] S. Barclay, *HIVIEW Software Package*. London, U.K.: London School of Business, 1984.
[45] J. H. M. Nogueira, J. F. L. Alcântara, R. C. de Andrade, R. B. de A. E. Silva, and R. S. Silvestre, *Group SINTA—Applied Intelligent Systems*. Ceará, Brazilian: University of Ceara, 1997.
[46] P. R. Pinheiro, I. Tamanini, M. C. D. Pinheiro, and V. H. C. de Albuquerque, "Evaluation of the Alzheimer's disease clinical stages under the optics of hybrid approaches in Verbal Decision Analysis," *Telematics Inform.*, vol. 35, no. 4, pp. 776–789, Jul. 2018.

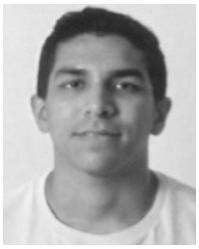
LUCIANO COMIN NUNES received the bachelor's degree in sciences economics from the Federal University of Ceará, Brazil, in 1988, and the master's degree in computer science and the Ph.D. degree in applied informatics from the University of Fortaleza, Brazil, in 2010. He was with the Bank of Northeastern Brazil (BNB), from 1976 to 2010, where he accumulated experience in the areas of management, information technology, human resources, finance, and credit. He was the Statutory Officer of the Camed Group, where he was the Director of Promotion, Health Care, and Information Technology (IT), from 2010 to 2013. During this period, he was a member of the Board of Directors of the National Union of Self-Managed Health Institutions. He was responsible for the Information Technology Secretariat, Court of Justice, Ceará, in the 2015/2016 biennium. He participated actively in the standing committees of BNB, including the Ethics Committee and Internal Commission for Accident Prevention. He was a representative member of BNB in the Free Software Implementation Committee, Federal Public Institutions of Brazil, an organ linked to the Ministry of Planning. He is currently an Adjunct Professor with the Centro Universitário 7 de Setembro, where he has been teaching subjects related to IT, auditing, and economics, since 2009. He received the title Specialist in Computer Science, in 1991.

PLÁCIDO ROGÉRIO PINHEIRO received the Ph.D. degree in systems engineering and computing degree from the Federal University of Rio de Janeiro, Rio de Janeiro, Brazil. He is currently a Titular Professor with the University of Fortaleza and an Associate Professor with the State University of Ceará. He has experience in industrial processes modeling applying mathematical programming and multicriteria. His academic formation allows publishing in applied mathematics area, with an emphasis on discrete and combinatorics mathematics, working mainly in mathematical programming and multicriteria. He has published in international periodicals with highlights for his citations.

MIRIAN CALÍOPE DANTAS PINHEIRO received the Ph.D. degree in nursing from the Federal University of Rio de Janeiro, in 1999, with a specialization in surgical medical nursing from the University of Fortaleza, in 1988, and with a specialization in pediatric and neonatal nursing from the State University of Ceará, in 1992. She is currently a Full Professor with the University of Fortaleza, where she was allocated to the Nursing Undergraduate and Professional Master's Program in Technology and Innovation in Nursing. She is also the Coordinator of the Study Group Technologies in Child and Adolescent Health Care, NUPESQ-CCS. She has experience in nursing, with an emphasis on pediatric nursing, working mainly in the following subjects: primary health care, nursing, pediatric nursing, adolescence, adolescent health education, community health, public health, family health strategy. She has published in national and international periodicals with highlights for her citations.

MARUM SIMÃO FILHO received the bachelor's degree in computing from the Federal University of Ceará, in 1990, the master's degree in computer science from the Federal University of Pernambuco, in 1994, and the Ph.D. degree in computer science from the University of Fortaleza, in 2017. He was a representative member of the Bank of Northeastern Brazil (BNB) in the Free Software Implementation Committee, Federal Public Institutions of Brazil, an organ linked to the Ministry of Planning. He has been teaching the undergraduate, postgraduate, and extension courses, since 1998. In addition to teaching, he has been working in the professional market, since 1994, accumulating several years of experience in systems development and project management, in addition to having held several management positions. He is currently with BNB. He is also the Coordinator of the degree in information systems and postgraduate degrees in systems architecture for the Internet, strategic management and IT governance, and data science with the Centro Universitário 7 de Setembro.

RAFAEL ESPÍNDOLA COMIN NUNES is currently pursuing the bachelor's degree in environmental sciences with the Federal University of Ceará, Brazil, and the bachelor's degree in information systems with the Centro Universitário 7 de Setembro. He participated in an undergraduate sandwich at Trent University, Peterborough, Canada, during 2014–2015, under the Science Without Borders Program. He is currently involved in bots applications with the use of artificial intelligence techniques embedded in IBM-Watson software.



PEDRO GABRIEL CALÍOPE DANTAS PINHEIRO is currently a Control and Automation Engineer. He is currently pursuing the master's degree with the University of Fortaleza under the Graduate Program in Applied Informatics. He works in the Research, Development, and Innovation Sector in electronic, electrical, and mechanical projects in the areas of oil, gas, defense, and entertainment. He has experience in mobile robotics projects and monitoring systems, embedded systems and microcontrollers, manufacture of printed circuit boards, technical analysis of industrial installations, maintenance of electrical panel, and supervision of maintenance. He is involved in developing microcontroller programming in C/C++ and python language. In teaching, he has experience in systems analysis and development, with an emphasis on unified modeling language, project standards, and computational mathematics.