**FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO**

# Machine learning and Data analysis about Disentangling Disorders of Consciousness

## Manuel Curral

PREPARAÇÃO DA DISSERTAÇÃO





Mestrado Integrado em Engenharia Informática e Computação Supervisor: Prof.Jaime Cardoso



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# Abstract

The diagnosis of people with disorders of consciousness (DOC) is vulnerable to misdiagnosis that can negatively affect their rehabilitation process. The incorrect diagnosis of people with DOC is common, reaching 43 %. This has possible implications for decisions regarding the provision of health care to this group. The diagnosis of this group depends on the assessment of their be- havioral responses to stimuli. The intentionality and types of behavior exhibited by people in a vegetative state (VS) and a minimally conscious state (MCS) can be difficult to distinguish and subtle signs of consciousness can go unnoticed. It is widely recognized that the use of standard- ized and sensitive behavioral assessment scales, such as the Sensory Modality Assessment and Rehabilitation Technique (SMART), can help healthcare professionals to identify subtle signs of awareness. SMART is an assessment tool that combines communication, motor and sensing func- tions to diagnose the condition of patients who have suffered severe brain injuries. This method is quite credible and accepted by the healthcare community that deals with this clinical population. It requires and consumes many resources in making the diagnosis.

However, less experienced SMART evaluators can be misled by some types of patient re- sponses and even in the analysis of session data, namely in different diagnostic limit zones. Hence a second opinion based on Machine Learning can prove to be very useful. In addition, the diag- nosis is made session by session and the cumulative diagnostic certainty as the sessions progress. This tool can be detected as well as the expert evaluators, in the future it can be very useful to detect in advance (in a smaller number of sessions) the state of consciousness of the patient to be analyzed.

SMART evaluation has already been explored with statistical software such as statistical pack- age for the social sciences (SPSS) combining analysis methods and techniques such as analysis of variance (ANOVA) etc So far, no machine learning methods have been found in partnership with this technique and diagnostic tools (SMART).

The best diagnosis, through a second opinion performed by the machine, is expected to in- crease the confidence level in decision making by SMART evaluators. More protected and less subject to criticism of negligence, data that possible errors if detected, can be bridged and safe- guarded or at least become noticeable therefore, it leads to higher hit rates. Minimizing the alloca- tion of time to human resources for this specific task, can be beneficial for these professionals due to the useful / effective time to perform tasks (elimination of extra hours to do a task that was pre- viously done). Institutions: speeds up the prognosis and diagnosis process, making it financially convenient to make professionals more free, resulting in greater performance and efficiency, with the possibility of performing other essential tasks.

**Keywords**: Machine Learning, DOC, consciousness diagnosis, SMART, minimally conscious state, vegetative state, brain injury,

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# Resumo

Pessoas com perturbações de consciência (PdC) são vulneráveis a diagnósticos errados que podem afetar negativamente o seu processo de reabilitação. O diagnóstico incorreto de pessoas com PdC é comum, podendo atingir os 43%. Isto acarreta possíveis implicações nas decisões relacionadas com a prestação de cuidados de saúde desta população. o diagnóstico desta população depende da avaliação das suas respostas comportamentais a estimulação. A intencionalidade e os tipos de comportamentos exibidos por pessoas em estado vegetativo e estado de consciência mínima, podem ser difíceis de distinguir e sinais subtis de consciência podem passar despercebidos. É amplamente reconhecido que o uso de escalas de avaliação comportamental padronizadas e sen- síveis, tal como o Sensory Modality Assessment and Rehabilitation Technique (SMART), pode ajudar os profissionais de saúde a identificar sinais subtis de consciência. O SMART é um instru- mento de avaliação que combina funções comunicacionais, motoras e de aferição de sentidos para diagnosticar o estado de pacientes que sofreram lesões cerebrais graves. Este método é bastante credível e aceite pela comunidade da área da saúde que lida com esta população clínica. Ele requer e consome muitos recursos na elaboração do diagnóstico.

Contudo, avaliadores SMART menos experientes podem ser induzidos em erro por algum tipos de respostas dos pacientes e mesmo na análise dos dados das sessões nomeadamente em zonas limite de diagnósticos distintos. Daí uma segunda opinião com base em Machine Learning pode vir a ser muito útil. Além disso, o diagnóstico é feito sessão a sessão sendo a certeza de diagnóstico cumulativa no progredir das sessões.

Esta ferramenta se detetar tão bem como os avaliadores expert, pode no futuro ser muito útil a detetar antecipadamente (num menor número de sessões) o estado de consciência do paciente analisado. - A avaliação SMART já foi explorada através de software estatístico como SPSS us- ando métodos e técnicas de análise ANOVA etc Até ao momento não foram encontrados métodos de machine learning em parceria desta técnica e ferramenta de diagnóstico (SMART).

melhor diagnóstico, através de uma segunda opinião realizada pela máquina é expectável que aumente o índice de confiança na sua tomada de decisão por parte dos avaliadores SMART . Mais resguardados e menos sujeitos a críticas de negligência, dados que possíveis erros se detectados, possam ser colmatados e salvaguardados ou pelos menos se tornem perceptíveis portanto, conduz a taxas de acerto mais elevadas. Redução dos tempos de alocação a recursos humanos destinados a esta tarefa específica, pode ser benéfico para estes profissionais pelo tempo útil de realização de tarefas (eliminação das horas a mais a fazer uma tarefa já realizada outrora). Instituições: agiliza o processo de prognóstico e diagnóstico, financeiramente conveniente tornar profissionais mais libertos consequente maior rendimento e eficácia com possibilidade de realização de outras tarefas primordiais.

**Keywords**: Aprendizado Máquina, Perturbações de consciência PdC,diagnóstico de consciência,

SMART, estado de consciência mínimo, estado vegetativo, lesão cerebral

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Manuel Curral

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*“You can’t stop the waves, but you can learn to surf. ”*

Jon Kabat-Zinn

*“O Universo criou um cérebro para permitir ver-se a si mesmo, para estar consciente de si*

*mesmo. ”*

Henry Markram

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# Abbreviations

API Application Programming Interface ANOVA Analyis of Variance

DOC Disorders of Consciousness DRS Disability Rating Scale GCS Glasgow Coma Scale

ICC Intra Class Correlation

fMRI functional Magnetic Resonance Imaging MCS- Minimally Conscious State Minus MCS+ Minimally Conscious State Plus

SMART Sensory Modality Assessment and Rehabilitation Technique WNSSP Western Neuro Sensory Stimulation Profile

TBI Traumatic brain injury

VS Vegetative State WWW *World Wide Web*

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**Chapter 1**

# Introduction

## Context

Consciousness is the individual’s ability to be aware of the knowledge of self and the environment. Furthermore, the ability to respond to various voluntary internal and external stimuli.[[13](#_bookmark20)]. In basic neurological terms, it is composed of awareness and wakefulness.[[17](#_bookmark24)] TBI is head injury that damage in the brain and his complex connections.

Condition **Wakefulness**

**Awareness**

Coma - -

.

|  |  |  |
| --- | --- | --- |
| Vegetative State | + to ++ | - |
| Minimally Conscious State | + to ++ | + |

Emerged from Minimally Conscious State ++ ++ Table 1.1: Disorders of consciousness categorization

This causes problems with how a person can think and interact with the world around him or her following a TBI, there are specific cognitive skills that are no longer functioning in the same capacity these cognitive skills our consciousness wakefulness or awareness attention perception or observation and recognition of information.

There are events that damage areas of the brain that control parts of the human body. And the patient’s faculties are conditioned. The origin of brain injuries can be:

* acute: as in a virus or hemorrhage
* traumatic: like road accidents, impacts where there are head injuries
* non-traumatic: such as drowning, sudden attacks on organs and consumption of substances harmful to the body

That cause brain damage that leads to consequences in terms of disturbing the person’s consciousness.[[15](#_bookmark22)]

After the coma, the rates of diagnostic errors, namely in the distinction between vegetative states and the minimum state of consciousness, are high *≈* 40 [[2](#_bookmark9)] [[8](#_bookmark15)] [[14](#_bookmark21)].

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1. *Introduction*

The diagnosis of the condition of the patient who suffers brain damage is made using scales to assess the behavioural response to stimulation: CRS-r, SMART, WHIM, WNSSP, Rancho levels physiancs etc. With technological advancement and the spread of its use, neuronal imaging tech- nologies such as: functional magnetic resonance imaging (fMRI), electroencephalogram (EEG) positron emission tomography (PET)

it has been possible to leverage the discovery and knowledge in the area of neuroscience and the identification, consequent diagnosis of the cerebral behavior of patients. This helps a lot in studying disorders of consciousness because it demonstrates the level of responsiveness that could not be obtained by the behavior scales already mentioned. [1](#_bookmark1)

Vegetative state (VS) is defined as absence of self awareness and the environment. Behaviours are limited to reflexive activities indicating no purposeful movement, neither experience of suffer- ing or evidence of comprehension [[12](#_bookmark19)]

Minimally Conscious State is serious but does not represent a complete lack of awareness re- sulting from widespread damage to the telencephalon (the part of the brain that controls thinking and behavior). The intentionally and types of behavior exhibited by people in a vegetative state and a state of minimal consciousness, they can be challenging to distinguish, and subtle signs of consciousness can go unnoticed. It is widely recognized that the use of standardized and sensi- tive behavioral assessment scales such as the Sensory Modality Assessment and Rehabilitation Technique (SMART), can help healthcare professionals identify subtle signs of awareness.

## SMART

SMART is an assessment tool that combines communication, motor and sensing functions to diagnose patients who have suffered severe brain injuries.

Five levels: no response, reflex response, withdrawal response, localized response and differ- entiated response

Advantage:

This method is entirely credible and accepted by the healthcare community that deals with this clinical population.

Disadvantage:

It requires and consumes many resources in making the diagnosis.

## Diagnostic tools

Neuroscientific technologies, experimental methods study the patients’ brain processes through many devices. Neuroimaging, psychophysical techniques or psychological tests are used to study processes such as learning, attention, memory, or emotion. [[5](#_bookmark12)]

The following stand out:

* + - Electroencephalogram (EEG)
  1. *Diagnostic tools* 3

Electroencephalography is a simple, non-invasive technique based on the recording and evaluating brain activity using electrodes placed on the skull surface. The electroencephalo- gram (EEG) is the record that results from the measurement of the electrical potentials of the brain. EEG shows the electrical fluctuation in the different locations of the cortex.[[3](#_bookmark10)] However it has the disadvantage of having an insufficient resolution to register the neuronal activity in deeper brain structures, such as the *nucleus accumbens* related to the processing of emotions.[[10](#_bookmark17)]

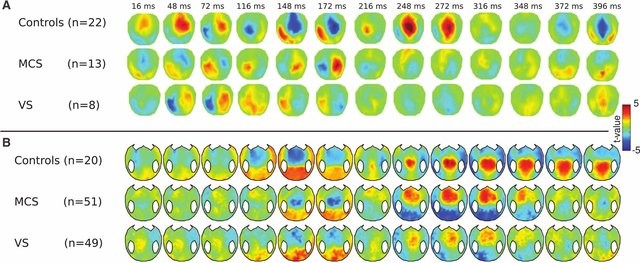


Figure 1.1: MMN topography in patients with disorders of consciousness and in healthy controls [[9](#_bookmark16)] [[4](#_bookmark11)]

* + - (Functional) Magnetic Resonance

It is a method of diagnosis and fundamental research in Market research Analyzing emotions Planning surgery Brain mapping neurosciences.[[6](#_bookmark13)] It allows the analysis of the subjects’ response to different activities or stimuli. Magnetic resonance imaging is a non-invasive technique used to obtain information about the subjects’ response to different stimuli (very common in research and analysis of neurological diseases such as alzheimer’s and also for soft tissue injuries and inflammation). This technique evaluates the activation and the emotional state of the subject when exposed to certain stimuli. [[7](#_bookmark14)]

* + - GSR (galvanic skin response)

Measurement of the galvanic response is done by placing electrodes on the fingers. Studies measure resistance skin and its conductance.

A GSR amplifier applies constant tension to the skin, of such a low voltage that the indi- vidual cannot perceive it through electrodes. The current generated in the skin by tension can be detected and recorded. The output of the GSR amplifier determines the conductance. The conductance of the skin gives feedback on the body’s response to the stimulus, it is widely used in post-coma and coma phases. [[1](#_bookmark8), [11](#_bookmark18)]

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* Eye-tracking

Eye-tracking refers to recording the movements of an individual’s eye while examining a visual stimulus. In broad, it is responsible for measuring eye movements using a camera that quantifies them. Modern eye trackers record eye position and movement using contrast to locate the central point of the pupil and create a reflection of the cornea using infrared light. It is possible to perform the analysis of the position of the gaze and the movement of the eyes in three-dimensional environments. Eye-tracking techniques apply to domains where interaction and interests matter, looking to sell or immerse to improve the customer or user experience. In medicine, it is essential to recognize behaviours and patterns to investigate further and be able to characterize.[[16](#_bookmark23)]

* Face reading

Facial expressions are one of the most robust visual methods for conveying emotions. The face plays a crucial role in the cognitive processes of individuals since the signs that show facial expressions denote internal states or emotions. The analysis of facial expressions pro- vides valuable information when combined with other tools that allow sensory information collection, such as eye-tracking or EEG (electroencephalography).

Research continues on clinical tools such as (fMRI) with improved diagnostic certainty and prognostic applications. There are 3 main factors that influence the prognosis of patients in the Vegetative State (VS) and the patient’s minimum state of consciousness (MCS):

•

Time (the longer you stay in the state, the more complicated functional recovery becomes)

•

* Age (young people have a higher recovery rate, linked to physiological recovery processes and brain plasticity)
* Type (if non-traumatic, there is a shorter potential recovery window)
* Note: The more severe the degree of injury, the rarer the recovery.

## Objectives

With the new discoveries in the fields of technology: more properly artificial intelligence combined with machine learning, we hope to help and give a more accurate diagnosis.

1. Classification in 2 possible stages (minimal state of consciousness and vegetative state)
2. Reduce time procedures diagnosis: after the first complete goal check, reduce the number of sessions to less than 10

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1. Try to find correlations between origin and possible stages and gauge the accuracy of results with basis on number of sessions available

**Areas:**

CCS →Computing methodologies →Machine learning CCS →Applied computing →Life and medical sciences

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**Appendix A**

# Definitions

Coma (from the Greek kôma = deep sleep) can be defined as a state of total or partial loss of con- sciousness, voluntary motor skills and sensitivity, generally due to brain damage, intoxications, metabolic and endocrine problems, without which, regardless of severity, vital functions are main- tained to a greater or lesser degree. When physiological, the state of coma can be measured using the Glasgow Coma Scale (GCSl) and when pharmacological using the Ramsay Sedation Scale (RSS).

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8 *Definitions*

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