

A NEW APPROACH FOR THE CHARACTERIZATION OF DENTAL DISEASES BASED ON AI

Autors: Marco Colombo (*), Angela Maiorana (*), Luigi Passariello (*), Giuseppe Passariello (**)

*CRSLaghi: Lake research and study centre, italian private scientific centre of research

** Ma.Pa.COM: ICT Company committed to the development of high added value solutions based on 4.0 technologies

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Abstract

This work describes how dental diseases, which we have essentially reduced to caries and periodontitis, differ fundamentally from many other medical diseases. Employing the most popular schools of thought in disease definition, naturalism and normativism, we have shown that they do not fit the characterization of the most common dental diseases. Our research showed that it is possible to characterize a dental disorder through a dynamic representation based on the dynamic and technological concept of patient profile (AI).

INTRODUCTION

Although dental diseases are the most widespread globally (WHO 2022), little philosophical work has been done on this type of disease to date.

The work addresses the reasons why naturalism and normativism are not suitable for providing a definition of the concept of dental disease. Therefore, a new conceptual method for the characterization of dental disease as it manifests itself and as it is perceived will be proposed.

Technological tools to support this method will then be introduced.

The logical path followed developed around the following questions:

- What is meant by dental disease in medicine?
- How common are dental diseases?
- Can dental diseases be characterized as diseases? How?
- What technologies can help characterize dental disease?

DISCUSSION

The discussion starts with the identification of a claim that clarifies what we want to hold up:

CLAIM: Despite being the most common diseases, dental diseases do not lend themselves to being defined with naturalism and normativism theories but they might integrate into a phenomenological model.

Now we can argue about reasons that confirm our claim.

What is meant by dental disease in medicine ?

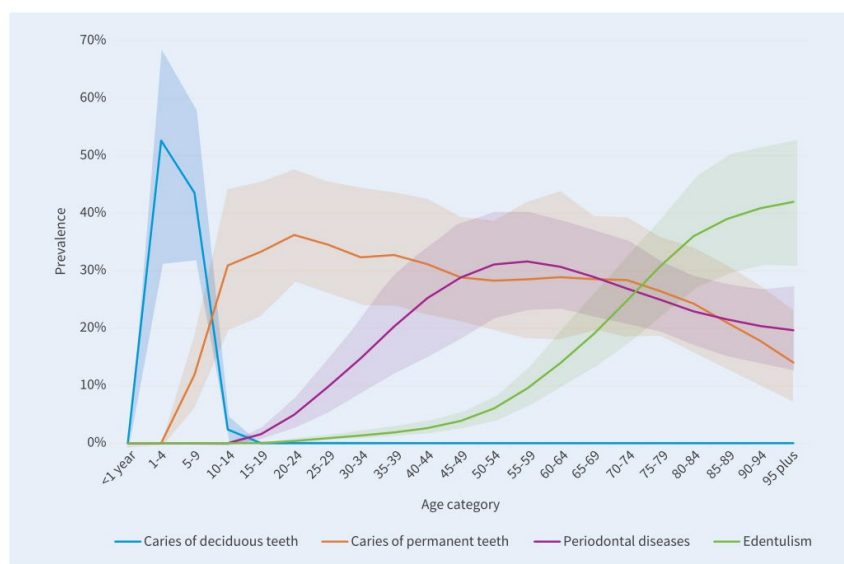
We know that dental diseases are the most prevalent in the world across all income groups (WHO 2022). They can be divided into 4 main pathologies:

- **Caries** is one of the most common pathologies and is the main cause of the classic **toothache**, frequent in both young and adult subjects. Caries originates from **bacterial proliferation** inside the oral cavity. Plaque and tartar bacteria transform the sugars, present in saliva, into acids capable of affecting the structure of the teeth, starting from the enamel, up to the root. Symptoms (soft, aching teeth) appear late. Caries are distinguished mainly according to the **evolutionary stage** in which they are found and the speed of progression:
 - **acute**, which evolve in less than a year;
 - **chronic**, with a slow and steady progression over a couple of years;
 - **relapsing**, who "come back" when not treated properly

Symptoms also vary according to the stage of the infection. **Diagnosis** is based on inspection, examination of the enamel surface with a thin metal dental instrument, and dental x-rays. The treatment is based on the removal of the affected tooth structure and reconstruction with various materials. Fluoride, good dental hygiene, sealants, and a proper diet can **prevent** virtually all cavities. Caries are essentially of two types:

- **Caries of milk teeth:** Caries in milk teeth occur much more easily than in permanent teeth, since the enamel is thinner and less mineralized and the "dentine", i.e. the substance of which the tooth is made underneath enamel is more fragile and thinner.
 - **Caries of permanent teeth:** it is the caries type affecting adult teeth
- **Periodontitis:** Periodontitis is a chronic oral inflammatory disease that progressively destroys the supporting structures of the teeth. It usually manifests as worsening gingivitis and then, if left untreated, with loosening and loss of teeth. Diagnosis is based on inspection, periodontal probing, and x-rays. Treatment involves cleaning teeth down to the gums and a vigorous home hygiene program. Advanced cases may require antibiotics and surgery.
 - **Edeuntulism:** Edentulism, or edentulism, is a clinical condition characterized by partial or total loss of teeth, which has consequences both on general health, due to incorrect nutrition, and on psycho-social health. The state of edentulousness is correlated with age, becoming of great importance after the age of 65.

Therefore by dental disease we can mainly mean caries and paradontis as edeuntolism, although it has its own pathological identity, is mainly a consequence of caries and paratonditis. In the following table we see how the main dental diseases evolve over the course of life according to age groups:



Note. Data are from GBD 2019 (4).

Figure 1. - Prevalence rates of four major oral diseases over the life course (WHO, 2022)

How common are dental diseases?

The Global Burden of Disease 2019 (Lancet GBD 2019) photographed the problem worldwide, in a study according to which dental diseases, and in particular untreated caries, represent the most common disease ever. Globally, it is estimated that as many as 3.5 people are affected by dental disease, of which 2 billion people suffer from permanent tooth decay, while 520 million children suffer from milk tooth decay (WHO, 2022). On the other hand, periodontal disease affects 14% of the adult population, with more than 1 billion cases worldwide, even in severe forms, with the gum that can detach from the tooth and from the supporting bone, thus generating mobility in the teeth until their fall.

Correlation between oral health and health in general.

In recent decades, many studies have evaluated the potential link between poor oral health and a range of chronic diseases (Seitz MW et al. 2019). Links have emerged between severe periodontal disease and diabetes mellitus; this strong link was also confirmed by improvements in diabetes status following clinical interventions for the treatment of severe disease (Gooch BF et al. 2009, D'Aiuto F. et al. 2017). Other studies have also found links between:

- severe periodontal disease and cardiovascular disease (Batty GD et al. 2018),
- oral health and chronic obstructive pulmonary disease (Manger D. et al. 2017) (Gaeckle NT et al 2020).

Other studies have found links between:

- tooth decay/loss and cognitive decline (Chenxin Tan et al. 2022), some types of cancer (Peres MA, 2019) and pneumonia (Son M. et al. 2020, El-Solh AA 2011, Pascual-Ramos V. et al. 2006).

These links are supported by

1. shared biological risk factors (infection, inflammation, microbiome and immune responses),
2. behavioral factors,

3. social factors.

However, it should be highlighted that links between poor oral health and other chronic diseases are weak compared to other factors that we could define as serious risk. In this sense, a more in-depth analysis is needed to investigate the causal link between poor oral health and other diseases as well as the impact of oral health protection interventions have on general health (Watt RG et al. 2020).

Limits of naturalism and normativism in the characterization of dental diseases

In recent decades, two fundamental conceptual visions of definition of the disease have emerged, the naturalistic theory and the normativist theory (Reznek L. 1987, Räikkä J 1996, Kova'cs J 1998). For naturalists, disease must be defined in terms of natural (biological) processes. They believe that disease is a worthless concept (Boorse 1977), existing independently of its social and cultural context. Disease can be discovered, studied and described by science; it is descriptive and not normative. According to proponents of the normative definition, on the other hand, there is no concept of disease without value. The concept of disease is invented and not discovered. It is contextual (King L. 1954, Fulford KWM. 1989) and given by convention (Kendell RE 1975, Engelhardt HT 1975). These theories address different aspects and pose different challenges.

The naturalist account

The most important and authoritative exponent of naturalist theory of the twentieth century is Christopher Boorse (Boorse 1975). He claims that a disease is an internal state that interferes with the body's natural function beyond normal statistical values:

"... a disease is a type of internal state of the organism which (i) interferes with the performance of some natural function – i.e., some species-typical contribution to survival and reproduction characteristic of the organism's age; and (ii) is not simply in the nature of the species, i.e., is either atypical of the species or, if typical, mainly due to environmental causes." (Boorse 1975)

The naturalist's view provides a report of normality in statistical terms by explaining the uncertainty of medical knowledge, but has the limitation of not providing advice and tools on how to deal with this uncertainty. In fact this can be done with rules. The purpose of the human being is defined as "typical contribution of the species to survival and reproduction".

Moreover Boorse claims that a disease is an individual's altered internal state leading to an

'impairment of normal functional ability (...] below a typical efficiency'

where normal function is based on what is statistically typical for the individual within a reference class (Boorse 1977). A Boorsian reference class is defined as a

'class of organisms of uniform functional design; specifically an age group or a sex of a species' (Boorse 1977).

In practice, if I don't function in the same way as other human beings in my peer group, I am considered ill. But how do the most widespread diseases fit into this concept? A counterexample is given by caries (Cooper R. 2002, Hausman DM 2016). Even Boorse himself provides this counterexample. He explains that because prevalent diseases such as caries are rare there is no need to 'fork' the definition to handle these cases (Boorse C 1997). Therefore caries should be considered a normal condition (Boorse C 1997).

If the "natural function" is determined by statistical normality, the definition of the limits of what we consider normal is not a matter of describing nature. If teeth are lost in old age, it makes sense to ask how many teeth are needed to maintain normal function. This implies that the naturalistic account depends on the normative notion of normality.

Furthermore, the mutations introduced by tooth loss cause a statistical difference, and therefore the mutations become cases of disease, even though they could contribute to adaptation, survival and reproduction and even represent the key to development through evolutionary selection (King LS 1954).

The naturalistic theory does not foresee values and norms because it is by definition valueless. But the need to define "normality" and "function" demonstrates that naturalist theory also has some normative traits.

The normativist account

There are several normativistic definitions of the concept of disease. Contrary to naturalist theory, they acknowledge that values and norms constitute the concept of disease. King (King LS 1954) presenting his ideas on "statistical norms" gives a classical account of this position:

“Disease is the aggregate of those conditions which, judged by the prevailing culture, are deemed painful, or disabling, and which, at the same time, deviate from either the statistical norm or from some idealized status.” (King LS 1954)

Disease, according to King, is determined by its cultural context. Others have claimed that disease is a result of man-made abstractions (Kendell R.E. 1975), or a concept that man applies to explain a situation of negative value for oneself (Canguilhem G 1991). Despite the different conception of disease (with or without value), the normativist shares a similar idea with the naturalist in the conception of reference classes.

In a more modern perspective, Cooper argues that disease is a normative phenomenon and must be conceptualized with strong sociocultural considerations (Cooper R. 2002). He points out that:

“roughly worse off than the majority of humans of the same sex and age” (Cooper R. 2002);

By saying this Cooper introduces the concept that a person afflicted with disease is unfortunate. He goes on to explain that illness, which is a bad thing, should predict potential medical treatments available (Cooper R. 2002). From a normativist point of view, we can attribute value judgments to our pathologies when an individual in our community is considered ill. In this case it is the society that judges, not biology.

Limits of the naturalistic approach applied to dental diseases

Dental diseases are almost omnipresent if we consider all the various pathological forms. The research results of the WHO (2022) confirm that 90% of individuals have dental diseases in their lifetime, but these are preventable and hypercontrollable diseases, for which there are sensitive, rapid, simple and non-invasive tests that allow their identification from an early stage.

If a set of diseases are nearly ubiquitous, they cannot be classified as rare; if they are preventable and hypercontrollable, it cannot be said that they are unexpected. But if a dental disease isn't rare and isn't unexpected, meaning it doesn't behave like most diseases, how should it be treated?

Boorse, using his BST (Boorse's biostatistical theory), provides an answer by saying that these dental diseases are simply not diseases. And he does so by pointing out that the reference classes shift in such a way that only severe dental caries causing unbearable pain or advanced periodontitis causing movement and loss of teeth should be considered as disease.

Contestation of Boorse's Explanation

This statement seems counterintuitive: if I have been diagnosed with mild caries, even if in a subclinical state (extremely early to show no evidence), I would definitely consider myself ill and consequently I would accept both treatments and changes in my lifestyle and habits. Indeed, if the condition were dismissed as a state of

health and not disease, the progressive nature of caries would do that severe symptoms would present themselves in a relatively short time. Knowledge of what is labelable as a disease and how and when it should be treated is extremely important to the ethics of any medical profession. Therefore, it is not pragmatic to simply relabel people with dental disease as "not sick", especially when Many of them may wish to seek treatment to remove or improve their condition

On the other hand, considering the data provided by the WHO (2022) on the prevalence of dental disease, it is not clear how a significant number of people with a highly prevalent disease can be considered normal in the same way as those without caries.

For this reason we believe that Boorse's BST does not lend itself to describing and characterizing the dental diseases that we have traced back to caries and parodontitis alone.

Limits of the normative approach applied to dental diseases

So let's try to apply the normative approach to see if it lends itself better to the characterization of caries by asking ourselves this question:

if I feel diseased and the dentist shows concern for my oral condition (for example for a diagnosis of caries), is it correct to classify this condition as a state of disease?

In the first instance we are certainly tempted to answer yes because I would definitely consider my fate to be bad and seek potential medical attention. But going deeper into the matter, this belief disappears. Let's see why.

We have said that in Cooper's (2002) modern normativist theory, he introduces the concept that if a person is afflicted with an illness is unlucky.

Contestation of normative approach of Cooper

Considering the possibility of prevention and monitorability of dental disease, it is not entirely clear how I could consider myself unlucky.

In this regard, Cooper explains that we can only "consider someone" sick if it is reasonable to hope not to be (Cooper R. 2002). When a group of diseases is preventable, it is mainly lifestyle factors that cause them.

In practice, it is I who decides whether or not to follow a diet rich in sugars and I am always the one who decides whether or not to conduct an adequate level of oral hygiene to avoid dental disease. For this reason, it cannot be a case of bad luck for me to experience an illness brought on by risky behavioral choices. In fact, it is well known that good oral hygiene and a low sugar diet guarantee good oral health. Therefore, the development of a dental disease such as caries or periodontitis cannot reasonably be considered an event due to bad luck.

There are exceptions. For example, if an individual has a concomitant congenital disease such as Parkinson's disease with dyskinesia, which compromises voluntary movement, he could have difficulty implementing adequate prevention. For these sufferers it is difficult or impossible to carry out the task of brushing their teeth. But in the absence of movement-limiting pathologies, since a dentist has the means to be able to easily and non-invasively check for the presence of dental pathologies in any part of the mouth, if I act in a way that is harmful to my oral health and i don't attempt to detect any of the dental pathologies described or, even worse, I choose to ignore the diagnoses when they are made, then I cannot be considered unlucky if I develop these diseases.

Consequently, even the modern normative conception introduced by Cooper is not suitable for the dental diseases we are arguing about.

A new approach for the characterization of dental disease

We have found that the dental diseases, that we have substantially traced back to caries and periodontitis, do not fit the definitions of classic medical disease, based on naturalism and normativism.

One reason is that neither of the concepts addresses the multidimensional aspects of human ailment. For this reason was introduced (Twaddle A. 1968, Twaddle A. 1993) (Nordenfelt L. 1993) the following concepts:

- **Disease** is a bodily or mental occurrence that tends to reduce the capacity of the organism.
- **Illness** is a subjective negative experience that tends to reduce the capacity of the person.
- **Sickness** is a social identity assigned to a human agent due to events that tend to reduce his or her social capacity.

Using these concepts, we are going to introduce a new approach to characterize dental disease.

This is necessary because the difficulty in establishing what is or is not a disease poses a series of problems on how to diagnose, treat and more generally manage individuals who present with symptoms and above all which treatment to assign to them. Moral and ethical questions arise; are we under-treating or over-medicalizing? How can we deal with this problem?

Since the naturalistic and normativist definitions are not adequate to characterize dental diseases, we could use other theoretical methods to characterize them, such as, for example, analyzing them from a phenomenological point of view, i.e. how they are perceived and experienced. So let's shift the focus to the illness (Rakhra D. 2019). This changes our experience of illness.

After all, phenomenology permits to describe any experience and specifically, by applying phenomenology to the concept of illness, it is possible to describe how the illness is experienced, regardless of the biological dysfunction that determines it and the social impact it causes. The use of phenomenology for the study of a illness is not intended to replace empirical scientific investigation into disease and medicine, but helps to delineate the distinction between medical science and clinical medicine.

Discussion of illness, in lieu of disease, takes into account not only the pathologies but the entire gamut of history and context within which it is experienced. With the phenomenological approach, toothache from dental decay is not simply a pain but also a disruption to eating, to socialising, anxiety, a unforeseen cost, a losing of quality life.

To date it has been little investigated and therefore there is a lack of knowledge on how to use phenomenology for the philosophical understanding of illnesses, that escape the classical definition of disease by using naturalism and normativism. If I consider how dental illness is experienced in a given context I must also consider that we are talking about common predictable and monitorable diseases for which there is the awareness of how to avoid them and why they develop. Therefore an dental illness experience may be lined with notions of failure and lack of self-discipline.

Carel, one of the few to have investigated the relationship between phenomenology and disease, has shown how an in-depth phenomenological understanding of illness can provide us with information on how we interact, manage and deal with diseases and human experience (Carel H. 2016, Carel H. 2013).

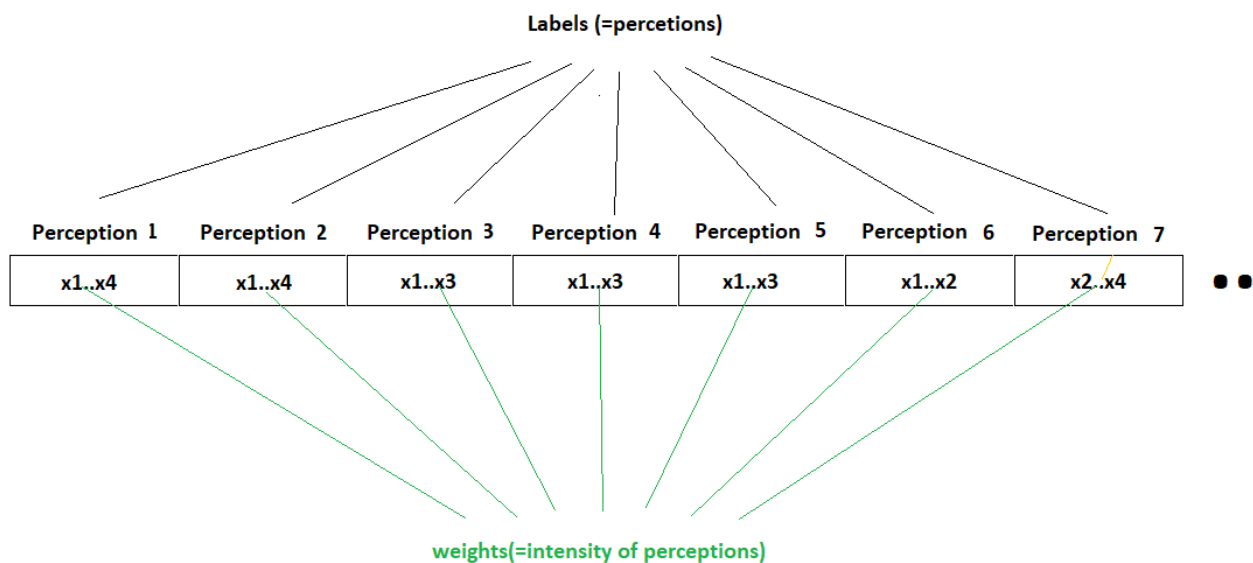
This approach leads to a more holistic medicine and, in the case of dental diseases such as caries and periodontitis, relieves the pressure for a professional definition of these diseases. If we can apply the phenomenology to dental diseases, we may be able to further expand the usefulness of phenomenology in wider illness.

AI to support the phenomenological characterization of dental diseases.

To represent the dynamism of the perception of illness, we can use Artificial Intelligence (AI) methods known as "user profiling" and "Smart Agents" (Albanese M. et al. 2006).

The use of "user profiles" to represent the illness for each individual and the use of "smart agents" (algorithmic model) to update the user profiles by recording the variations in the perception of the discomfort felt by the person over time due to the illness, would allow the extraction of common factors among the perceptions of different people useful for delineating the characteristics of dental diseases.

Consequently, it would be possible to arrive at a valid characterization for all forms of dental disease. To represent a user profile we can think of a dynamic vector of labels (perceptions) and values/weights (intensity of perceptions).

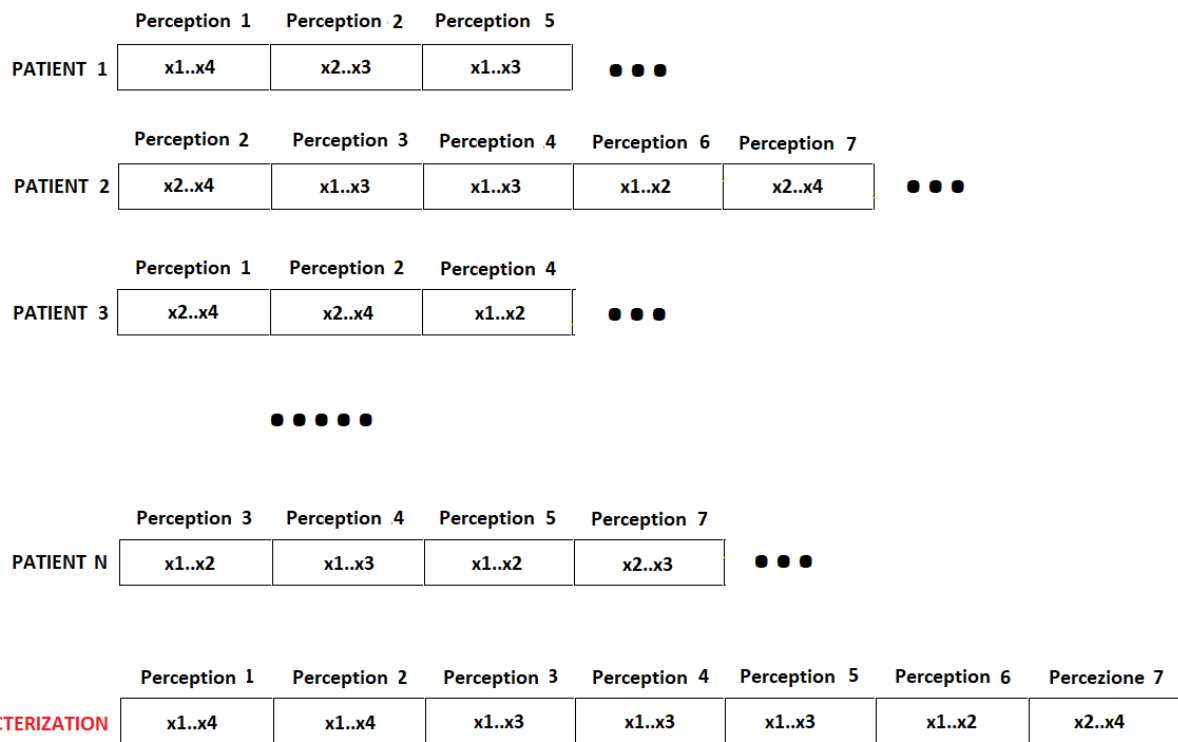


In other words, a new characterization of the phenomenological atypicality of dental disease would be given by the set of common characteristics that could be used to define the boundaries of what is dental disease or not. Thus the concept of class already used in naturalism and normativism returns.

Smart agents, at each medical consultation, or at each repository of knowledge on the specific symptoms of illness experienced by people, adaptively update or add labels and values for each individual patient.

Since it is reasonable to think that the type of perception and its intensity tend to saturate over time, it will be possible to obtain a characteristic profile of the disease which represents the union of all the perceptive factors (perceptions) and all the intensities (weights) that characterize them.

To represent the variation over time of the discomfort perception of illness in an adaptive way for a multiplicity of patients we use the following dynamic representation:



The number of subjective perceptions of the illness is not fixed a priori but saturates over time for a significant sample of people affected by dental diseases. Referring to the previous vector, the result will be:

“I have dental disease if I feel:

- *Perception 1* with intensity of discomfort from x1 to x4,
- *Perception 2* with intensity of discomfort from x1 to x4,
-
- *Perception 7* with intensity of discomfort from x2 to x4.”

The method introduces a privacy problem related to identity of the patients to whom the medical data belongs. In accordance with the European Regulation on Privacy (GDPR, 2016), the problem can be easily solved by using pseudonymized data because uncorrelating the perception data from the patient's personal details, in addition to protecting privacy of them, does not limit the ability of the method to arrive to the characterization of caries as a illness, for effect of the saturation in the time of perceptions and of their intensity

A limitation of the technology is that it requires large-scale application in order to better characterize the boundaries of the disease.

CONCLUSIONS

This analytical work describes how dental diseases, which we have essentially reduced to caries and periodontitis, differ fundamentally from many other medical diseases. Employing the most popular schools of thought in disease definition, naturalism and normativism, we have shown that they do not fit the characterization of the most common dental diseases. Although they are almost ubiquitous, preventable and hypercontrollable diseases, they

- do not satisfy the concept of deviation from a reference class and
- do not satisfy the notions of being unlucky.

This questions whether dental diseases should be considered real diseases and raises ethical problems regarding their medical treatability.

For this reason we have explored how the phenomenological method can give us another way of conceptualizing disease in terms of how it is experienced. While not designed to replace philosophical definitions of disease such as naturalism or normativism, phenomenology allows us to engage in a discussion of dental disease, in which we can discuss the experience of a disease and the effect it can have on a person's life, for example, the disruptions and anxieties it can cause. This, in turn, informs and helps a practitioner manage patients and their illnesses ethically. Finally, we have described an AI method that can be used to support the phenomenological method for characterizing dental disease as it is experienced.

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