Artificial Intelligence (AI) in the Dentist's Work: The Perspective of Anthropomorphization and Cognitive Aspects of the Decision-Making Process

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Abstract: This research aims to evaluate the performance of an artificial intelligence (AI) tool called CranioCatch, which assists dentists by examining the anthropomorphization and cognitive aspects of the decision-making process. It remains unclear to what extent technology replaces or complements the work of healthcare professionals. Additionally, the specific cognitive aspects of the decision-making process attributed to CranioCatch, characterizing the anthropomorphization of the technology, have not been mapped. The methodology employed included "instruction to the double," "shadowing," and interviews. The study reveals how CranioCatch replicates cognitive activities performed by dentists by comparing, correlating, and associating images from a specific patient with similar images in a database. Through these steps (comparison, correlation, and association), which constitute the identification of the problem, it is possible to develop alternatives and select the best solution for the patient's situation. Thus, AI contributes to both the identification and action aspects of the decision-making process. From a physical perspective of anthropomorphization, the primary characteristic replicated by AI was the sense of vision. Regarding contributions to dentistry, the AI technology studied enhances the efficiency of professionals, notably reducing evaluation and diagnosis times. Due to its rapid and accurate analysis, AI is believed to significantly improve the work of healthcare professionals.

Keywords: Artificial intelligence, Radiographs, Decision-Making, Cognitive aspects

1. Introduction

The use of artificial intelligence (AI) technologies in healthcare is revolutionizing the work of professionals (Cordeiro *et al*., 2023; Reis *et al*., 2023). Due to demand, AI applications have been a rapidly developing field of study in dental radiology in recent years (Başaran et al., 2022; Reis *et al.*, 2023a). Considering the health sector, with a focus on dentistry, there are several AI technologies working, such as CranioWatch, an initiative that emerged from academic studies with the aim of evaluating dental x-rays (CranioCatch, 2023).

It is not known to what extent technology replaces or complements the work of healthcare professionals (Reis *et al.*, 2023b). Furthermore, it has not been mapped which cognitive aspects of the decision-making process are attributed to the CranioCatch technology, characterizing the anthropomorphization of the technology. Articles like Gorenstein (2023), Putra (2022), among others, reinforce the need for more studies and tests aimed at the use of AI in the healthcare area. Van Leeuwen et al. (2021) also mention that history has shown that validating these innovations in the real world is essential for decision-making. In this sense, this research seeks to evaluate the performance of an AI technology called CranioCatch, that operates in the dentist's work, from the perspective of the anthropomorphization and cognitive aspects of the decision-making process. Anthropomorphization consists of the incorporation of human abilities, including physical, cognitive and mental ones, into technical devices (Blut et al., 2021; Pelau, Dabija, Ene, 2021).

As there is a greater domain of cognitive characteristics involved in the decision-making process, a comparison of the activities performed by the AI with the dentist's work was carried out. The results aim to contribute to the use of AI, mainly in the dental area, from the moment in which the processes have been mapped and which characteristics are performed by the technology in facilitating and supporting the dentist's work.

2. Theoretical Reference

One of the most beneficial characteristics of AI is its ability to process significant volumes of data to provide results without the need for human action (Reis *et al.*, 2023a). Action which has proven to benefit multiple healthcare sectors that include bioinformatics, genomics, and image analysis (Gopinath, 2022). With the AI studies that have developed in recent years, a new opportunity for a solution has emerged in the diagnostic and image quality processes (Dicle et al., 2023). But, according to the literature, despite the performance of AI

with software such as CranioCatch (Başaran et al., 2022), U-Net network (Lin et al., 2021), among other algorithms based on deep learning (Kuwayama et al., 2019), (Shan et al., 2021), in which computers automatically learn from large sets of data in the field (Başaran et al., 2022), little is known about how it is changing the quality, efficiency, and costs of healthcare (Van Leeuwen et al., 2021).

2.1 AI in Dental Imaging Exams: CranioCatch Technology

AI is one of the most important technological developments that has caused deep changes in the life and production model of contemporary societies (Başaran et al., 2022; Cordeiro *et al.*, 2023; Cordeiro *et al.*, 2024). In recent years, AI research has rapidly emerged and developed in the field of dental and maxillofacial radiology (Putra, et al., 2022) and this can impact and add value to the healthcare community (KIM D., et al., 2022). Furthermore, AI studies in dentistry report that Deep Learning is promising in detecting many pathologies (Başaran et al., 2022). Thanks to the improvement of AI models in dental radiology, it is possible to predict the application of this technology by doctors in panoramic diagnosis and treatment planning (Başaran et al., 2022).

In dentistry, AI technologies have the potential to improve agility and effectiveness in diagnosis and clinical practice. To date, much research has studied AI applications in dental radiology, determining tooth numbering and detection, periapical pathology detection, caries detection, and restoration detection (Başaran et al., 2022). Table 1 presents some tools already on the market, according to the bibliography, and what their relationships are with the dentist's work.

Table 1: AI algorithms present in dentistry

Exam	Technology	Functionality	Benefits	Author	Aid x Replacement
Tomography	CNN model (deep learning)	Automated detection of chorioretinal diseases	Automated detection of macular diseases from Optical Coherence Tomography (OCT) images may be feasible using the CNN model	Kuwayama et al. (2019)	Improves work (replaces detection)
	U-Net network	Comparison of stock images	Perform automatic and accurate segmentation of the pulp cavity and tooth in cone beam computed tomography images.	Lin et al. (2021)	Assists with clinical work and tasks
Radiography	CranioCatch	Efficiently analyze 2D x-rays and quickly provide results to doctors	Detection of dental conditions on panoramic radiographs, except for cavities and dental calculus	Başaran et al. (2022)	It helps doctors in panoramic diagnosis and at the treatment planning
	THERE algorithms	AI in dental x-rays has shown great potential for a wide variety of purposes and can play an important role in assisting doctors in making decisions in the process	Current development of AI in dental imaging is not mature enough and requires substantial resources	Putra et al. (2022)	Assists doctors in the decision-making process.
Clinic	AI algorithms	Algorithms take unlabeled data and involve recognizing hidden data patterns that researchers may not have conceived of, producing unknown results. Principal component analysis and kmeans clustering are common methods used in learning.	Advancement in digitized technology for clinical examinations has made collecting healthcare data from dental patients less complex and cumbersome	Shan et al. (2021)	Assists with clinical work and tasks

Source: Prepared by the authors.

The technologies present on the market vary in the scope of their operation. Table 1 was organized so that the lines represented the different technologies. It is possible to observe the specific areas in which each technology operates, the main benefits presented in the literature and their relationship with the

professional's work, that is, whether the technology is assisting in the work or is replacing some function of the worker.

In the present work, the technology studied was CranioCatch, due to its per-positive and successful training in x-ray analysis. This technology has great potential to contribute to the dentist's work. The AI model is based at the Convolutional Neural Network (CNN) deep learning method. It proposed to detect ten different dental situations, rated as successful in detecting dental conditions on all panoramic radiographs except for caries conditions and dental calculus (Başaran et al., 2022). In dentistry with CranioCatch, solutions will improve the quality of healthcare, allowing patients to be treated faster and more accurately. This software selects the images to be analyzed and loading them into the system, returning the x-ray with the diagnosis in seconds. In this sense, dentists will be able to provide a better service to patients, obtaining results more reliable in x-ray analysis (CranioCatch, 2023).

2.2 The Relationship Between AI and Cognitive Aspects of the Decision-Making Process

When it comes to decision-making, AI emulates the cognitive abilities of human beings, in the sense of automating some decisions (Gopinath, 2022). Research into AI began shortly after the emergence of modern computers, with the goal of building intelligent "thinking" machines. Since the birth of AI, interactions between it and brain science have been carried out (Fan et al., 2020). Still according to Gopinath (2022), there are two ways in which neurosciences inspire AI, one being its ability to imitate human intelligence and the other ability to develop a neural network, which can imitate the structure of the human brain.

A decision is defined as a moment in a continuous process of evaluating alternatives related to an objective, in which the decision maker's expectation regarding a certain course of action impels him to select (Harrison, 1981). The beneficial relationship between AI and neuroscience is reciprocal, and AI has currently been widely investigated in the context of neuroscience. In this sense, AI in different situations produces results equivalent to those of human beings, emulating human intelligence. Therefore, a simple way to develop AI is to combine it with brain science and related fields such as cognition science and psychology (Fan et al., 2020). The literature presents some theories that describe the decision-making processes, and the cognitive aspects present in decision-making. Table 2 presents these theories.

Table 2: Elements of decision-making

THEORY	COGNITIVE ASPECTS	DESCRIPTION	AUTHORS
Decision-making process	Assess and determine	Ascertain the truth, determine a course of action, and persuade.	Barnard (1938)
Decision-making process on bounded rationality	Intelligence, design and the choice	Intelligence: Search, interpretation and supply of factors relevant to the decision, such as data and information. Design: Choice of methodology to be used or alternative paths that bring potential gains. Choice: Option for a line of action involving judgment and values, implying the renunciation of other alternatives.	Simon (1965)
Decision-making process	Recognize, identify, evaluate and choose	Recognition of a situation that requires a decision; Identification and development of alternative courses of action; Assessment of alternatives; choosing one of the alternatives and implementing the selected course of action.	Newman (1971)
Strategic decision process	Identification, development, selection	1- Opportunities, problems and crises are recognized and relevant information is collected and problems are identified more clearly; 2- Alternative solutions to problems are generated and modified; 3- The alternatives are analyzed and scanned and an alternative is chosen.	Mintzberg (1976)

Source: Prepared by the authors.

From the elaboration of Table 2, achieving a visual model that allows comparison between different theories, it is possible to identify which are the most common cognitive aspects present in the decision-making process. Authors such as Simon (1965) and Mintzberg (1976) theorized decision-making by dividing it into phases, basically the first two being associated with information collection and identification and the last phase linked to the action to be performed and information processing. Based on the relationship between such theories, it is possible to divide the decision-making process into two main stages: information collection and information processing.

3. Methodology

This study was divided into two stages. After analyzing the literature and websites that address the technology of CranioCatch, the first stage began with data collection. The dentist´s work process was mapped using data collection and checking methods: 1 - “instruction to the double” and 2 - “shadowing” After data collection, the second stage began. At this moment, the work process flow was designed and activities that could replace or complement the work of the health professional were identified.

The method of “instructing the double” emerged in the 1970s, during the Italian Workers Movement (IWM) with the doctor Ivar Oddone (Pereira, 2017). In order to provide a better understanding of the processes between interviewee and interviewer, the proper technique involves promoting the interviewee in a position of educator. The interview was conducted remotely, via Google Meet for approximately 50 minutes. A sequence of questions was asked about how treatments were carried out, how anomalies were identified in examinations, whether it was possible to observe some type of pattern and how artificial intelligence could act in the area.

The "instructing the double model" should avoid questions that express motives or reasons such as “why?”, so that the interviewee does not feel coerced, which would lead to the omission of some information for fear of incorrectly speaking about a process. Questions like “how to do it?” and “what should never be done?” are prioritized. All processes were noted while the professional responded, with more details being requested in some situations. After completing the interview, a work process flow was created that would be duly validated after the shadowing analysis.

With the intention of corroborating the responses obtained, the “shadowing” technique was used, a research technique that involves a researcher closely following a member of an organization over an extended period (McDonald, 2005). By having the action processes mapped, and with the authorization of the professional and the patient, it was possible to monitor some services to analyze in practice what was being done and how the professional's decision-making was made. Two patients were monitored, whose consultations lasted around 30 minutes, and who had already undergone the x-ray procedure. It was possible to monitor how the professional identified the injuries (using the senses, such as touch and vision, and clinical experience), how the report was provided and how the treatment was conducted. All analyzes carried out in this data collection stage were being meticulously compared with what had been reported by the dentist during the first interview, thus being able to validate the previously prepared work map.

The focus of the questions and follow-up was to understand as much of the work processes as possible, to obtain a stage map. Therefore, the creation of a visual analysis model would help in understanding how each process is carried out, and what is necessary, such as: experience, use of the senses and comparisons, to obtain a diagnosis and propose a treatment. Upon finalizing the workflow map, it was presented to the professional for final verification. The analysis consisted of comparing the data obtained in both methods with the performance of CranioCatch presented in the bibliography and pointing out in which fields of work the technology is applicable.

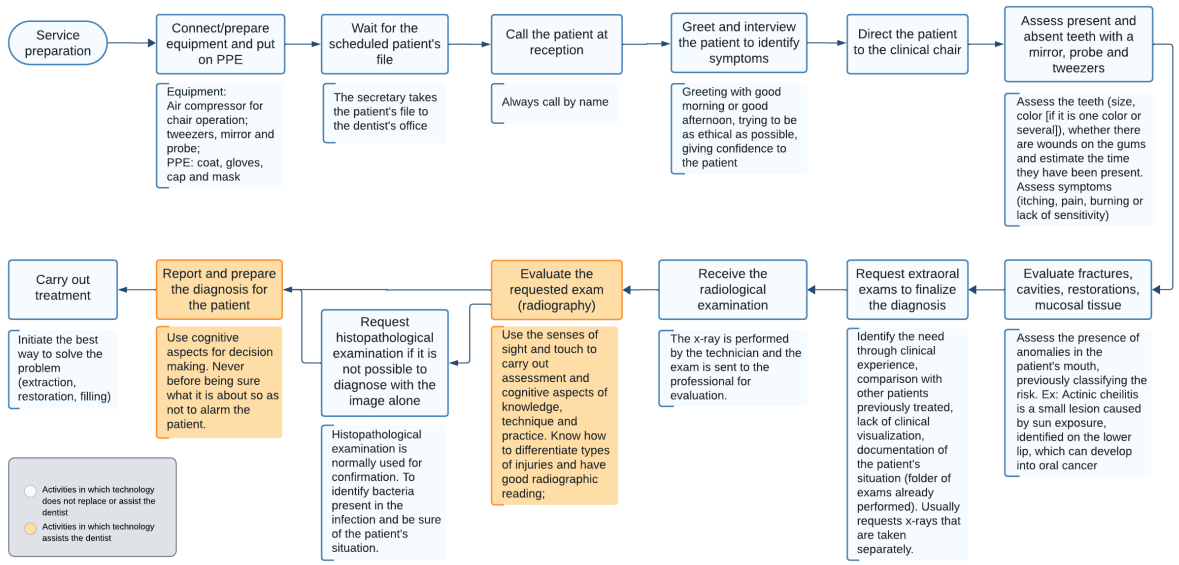
4. Data Analysis

In dentistry, the professional's work includes physical and mental activities that, combined, can generate a complex working day.

4.1 Dentist´s Workflow: Identification of Activities That can be Replaced or Complemented by AI

To identify where AI is used to replace or complement human work, a mapping of the activities involved in the dental patient care process, as shown in Figure 1, was created. All mapped actions come from the professional's perspective. After data collection was completed, the workflow model was developed. All the

processes described were highlighted by the interviewed professional, from calling the patient to the room to presenting the report. Each box represents an action performed during the activity.



Source: Prepared by the authors

Figure 1: Dentist´s workflow

The workflow analysis consisted of identifying which processes/actions could or are already replaced by AI technologies. The light blue boxes represent activities that, in principle, could not be replaced by AI. Just the radiography and emission assessment activities of the report were considered as possible to have the assistance or support of AI, highlighted in orange in the flow image. In a dentist's work, with an emphasis on image analysis, the evaluation of x-rays can take up a lot of the professional's time, and it is possible for some details to go unnoticed.

4.2 Anthropomorphization of CranioCatch Technology

The decision-making process was evaluated in two parts: the first which addresses the collection of information from the senses and the second which corresponds to the processing of this information collected from cognitive aspects. Regarding the first, it was observed that of the five senses, the CranioCatch technology only explores “vision”, in the sense of perceiving and visualizing the image of an x-ray. So, after “viewing” this image, it starts processing this information. Thus, the cognitive aspects reproduced by technology, in the analysis of x-rays to facilitate decision-making by the professional, are represented in Table 3.

Table 3: Anthropomorphic aspects of the CranioCatch

CRANIOCATCH DECISION-MAKING PROCESS ASPECTS				
IDENTIFICATION			**ACTION**	
COMPARISON	**CORRELATION**	**ASSOCIATION**	**DEVELOPMENT OF ALTERNATIVES**	**SELECTION**
Compare the image with other images to analyze similar situations	Identify similar images (relate images) to predict/outline diagnoses	Associate nearby images with atypical situations, from which there is knowledge about what type of anomaly it may be	Once the diagnosis has been defined, identify alternatives to solve the problem: complementary actions are defined to complete the diagnosis and/or immediate intervention.	Selection of the alternative that best suits the patient's situation.

Source: Prepared by the authors.

The preparation of the table consists of presenting which activities the CranioCatch software performs, in order to reproduce cognitive activities carried out by dentists. In this case, it executes comparison, correlation and association with nearby images to identify diagnostic possibilities. Finally, he prepares a report. The

evaluation action and result of the technology takes place in seconds (CranioCatch, 2023) enabling greater agility in work and providing support in professional decision-making.

5. Discussion

Considering the limited understanding of the extent to which technology replaces or complements human work, particularly in the context of healthcare professionals. Furthermore, there were no maps of which human aspects are attributed to the CranioCatch technology, characterizing the anthropomorphization of the technology.

It is an AI trained to evaluate imaging exams, in which categories of situations are identified. The stages of developing alternatives and selecting the result of the CranioCatch technology involve image selection, analysis (comparing, relating and associating the new x-ray with images from your database) and presentation of the result.

With its focus on the area of dentistry, the AI technology studied presented characteristics that help the professional's work, reducing evaluation and diagnosis time. Technology assists in carrying out diagnosis and evaluating treatments that may occasion better treatment results. Other positive aspects are the greater safety for the patient, increased production and reduced service time due to its capacity to analyze large volume of data related to different patients comparing situations at different stages of the treatment process.

CranioCatch reproduces anthropogenic activities generating diagnosis and is classified as successful in detecting dental conditions on all panoramic radiographs. Once elements of the theory of decision-making processes were applied to AI, the reproduction of cognitive aspects was observed, mainly in the identification phase. Based on theories that explain how it is carried out and what the stages of decision-making are, mainly on Mintzberg's theory (1976), it was possible to identify and map which cognitive aspects the technology reproduces. A further step towards understanding the extent to which technology assists or can replace human work, so far, in radiographic analysis. However, the possibility of being used in clinical analysis and diagnoses in the future cannot be ruled out.

Other studies have sought to evaluate the use of AI in healthcare work processes (Reis *et al.*, 2023a; Van Leeuwen et al., 2021; Shan et al., 2021). However, this study at the level of AI applied to the work of dentists which use the sense of vision for recognition and collection of information to cognitive aspects for processing the information collected. The main contribution of the research is to analyze the relationship of AI in decision-making in a dentistry work process, surveying the cognitive aspects of decision-making. From this, assessing how an AI partly replaces and complements this work.

6. Conclusion

Technology assessment CranioCatch from the perspective of anthropomorphization in the dentist's work, made it possible to verify situations in which the use of AI can replace or complement the dentist's professional activity, in the evaluation of x-ray exams.

The technology acts cooperatively in the professional's work, supporting decision-making with a quick analysis of the x-ray. Relating the processes carried out by AI with decision-making theories contributes to studies related to AI, especially in the health area.

As limitations of this study, it is impossible to verify performance of the software in the evaluation of radiography and the comparison of efficiency between the dentist's evaluation. Since there were no statistical tests for comparison. Furthermore, there is a lack of the patient's existing clinical knowledge, which may impact the outcome of the report. Once during the interview carried out with the dentist to obtain data, it was emphasized by her that the patient's clinical record and the examinations and treatments carried out in the past are linked to the evaluation and the result.

For future work, it is suggested to conduct interviews with more professionals, including those who use technology to obtain feedback on how useful it is in their daily lives. It is also suggested to carry out statistical tests to compare the efficiency of AI and dentist assessment.

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