

**The State of the Art connecting Socioenactive systems with  
Artificial Intelligence and the Emotional Contagion  
Phenomenon**

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# The State of the Art connecting Socioenactive systems with Artificial Intelligence and the Emotional Contagion Phenomenon

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## Abstract

The Socioenactive approach is a new field of study exploring novel dimensions of the design and development of computational systems. Socioenactive systems are computational systems that consider the human brain, body, and the environment surrounding it in the design of interactions. This promising research area brings new perspectives to the Human-Computer Interaction field, studying phenomena that occur in humans’ brains, bodies, and their environments, considering cognition, sensorimotor processes, perception, and emotions. In socio-emotional interactions, the emotion contagion phenomenon emerges through bodily expressions, in particular, through neurophysiological expressions. Artificial Intelligence (AI) is being used to analyze emotions from human neurophysiological data. This study conducts a literature review concerning socioenactive systems associated with AI and the Emotional Contagion Phenomenon. Considering the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, we guided our search for relevant studies. We identified studies from four different search libraries. We conducted a screening process based on the titles and abstracts of these investigations. After applying the exclusion criteria, we filtered and selected several studies. We analyzed the selected studies based on their main keywords and related concepts. We analyzed these studies considering their relevance for future studies.

## 1 Introduction

Recently, the socioenactive approach has emerged involving contemporary technologies and new ways of considering the Human-Computer Interaction. This approach particularly investigates the coupling of human (social) activities that occur in places (environments) where people interact with each other and with ubiquitous computational systems present there. It aims to ensure that the actions and perceptions occurring during these interactions operate in a way that feeds back into the system, providing it with dynamism. This dynamism, in turn, is not goal-oriented and is not limited to graphical interfaces and conventional input and output devices. It contributes to Weiser’s original vision of “invisible” ubiquitous technologies [2].

The new investigations considering this approach revealed challenges in the field because it involves practical implications in the way we design for our living (in) the world, including the meanings for the body, for other bodies, our differences in the coupled relation to the technology-enhanced environments, and the complexities of the methods demanded [?]. Socioenactive systems require the development of multimodal technology that is coupled to the human body and the

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environment in which it interacts [3] [50]. Ubiquitous computing is extensively used in socioenactive systems because it allows coupling to the human environment and body.

Ubiquitous Computing involves devices that can be everywhere and accessible at any time [57]. These devices contain microprocessors and tiny sensors that are interconnected by a network. In an environment with ubiquitous technologies networked, information resides on the network or in a single device, so that they can catch, receive, or share information among several devices [57][1]. Studies inspired by ubiquitous technologies have been conducted; for instance, a corporate identification badge was developed, based on sensors that contain a microprocessor, which broadcasts the wearer's identification in the environment to open doors, route telephone calls, and customize computer displays [57].

Wearable technologies are part of the concept of ubiquitous computing, as they afford continuous connectivity with body-worn technologies [20]. The use of wearable technologies is expanding across various industries, including art and fashion. For instance, you can find dresses and garments with wearable devices that incorporate computational technologies to characterize and present the wearer in a particular way to the audience, impressing, surprising, and delighting them [9]. Wearable technologies can intervene in social situations proactively, supporting both wearers and non-wearers to interact with one another in novel ways, thereby bringing people closer together. It can support social activities such as playful interaction, task-oriented interaction, collaborative creation, or other activities that require interaction between people [9]. In our view, ubiquitous and wearable technologies can help bridge the gap between people and digital technology in various ways. It could strengthen social relationships by immersing people in a computational world.

Emotions play a significant role in social relationships, and emotional contagion can occur between two or more individuals. According to Hatfield [22], emotional contagion is a phenomenon "whereby one person 'catches' emotion from other individuals" [22, p. 24]. It involves corresponding or complementary manifestation in facial, vocal, and postural expression [22]. In this process, our body responds with neurophysiological activities involving our organs, nervous and cardiac systems, and others, which is reflected in our emotional responses. The consequence of emotional contagion is the synchrony of emotions in social groups. For example, children who are in hospitals are sometimes visited by clowns to help them improve their emotional states and deal with stressful and painful medical procedures. The clown's facial expression (with a smile), voice tone, and posture attempt to influence children's emotional state and make the hospital experience more bearable. It is an example of 'emotion contagion' that can occur within our family, among friends, or persons surrounding us [51].

Within this process of emotion contagion, our perception is actively at work. The person whom I see, his voice which I hear, and his hand which I shake, are involved in a unified space. Our perceptual capacities are involved in the course of our interaction with the world, implying a continuous circularity of perception and motion [15]. At this point, our senses play an important role because through them, we perceive the world around us. They function as a channel of communication between our body and the environment. Our sensorimotor capacities are integrated in the interaction with the environment. Our relationship with the environment is a feedback loop of "receptive" and "effective" process flow. Our sensory organs act as receptors, and the motor organs respond as effectors. This is referred to as the embodiment of cognition [15]. All around us is brought continuously by our sensorimotor interaction with the environment [28]. Our brain and body are centrally involved in this dynamic relation, in which neural and physiological activities are involved.

Artificial Intelligence (AI) plays a crucial role in the analysis of neurophysiological information. These studies involve pattern recognition, and several techniques are explored, created, and experimented with to improve the accuracy of pattern recognition. In the field of emotional contagion,

AI is a relatively underexplored area [23], and in the last year, a few studies have investigated emotional contagion considering neurophysiological information [33]. To the best of our knowledge, the studies on emotional contagion involving the socioenactive approach and AI have not yet been explored in the literature. No studies delving into human perception, cognition, and sensorimotor level, where neurological and physiological responses are involved in socio-emotional interactions. In particular, there is no study investigating the emotion contagion phenomenon in this context.

This study aims to investigate a systematic literature review involving the socioenactive approach, AI, and/or emotional contagion. We aim to identify and describe the main underlying concepts associated with these areas. This work seeks to address the following research question: "What is the state of the art of socioenactive systems involving AI and the emotional contagion phenomenon?" We believe that emotions play an essential role in social interactions. The socioenactive approach enables the analysis of HCI under the phenomenological perspective. Studying the emotional contagion phenomenon from a phenomenological perspective is a significant challenge.

We conducted a literature review to gain a deeper understanding of studies investigating socioenactive systems, AI, and emotional contagion. First, we reviewed, analyzed, and described the main concepts involving socioenactive, emotion contagion, and AI. Afterwards, through the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) [38], our literature review was conducted. From this, we identified related studies and analyzed existing research. We delved deeper into the selected studies to reveal their contributions and gaps.

The remainder of this work is organized as follows: Section 2 presents a theoretical background. Section 3 describes the methodology and obtained results regarding the analysis of related studies. Section 4 discusses the results. Finally, the conclusion 5 follows.

## 2 Theoretical Background

In our review of the main concepts related to socioenactive, AI, and emotional contagion, we identified several key concepts. We developed a relationship among them, resulting in a conceptual map. Figure 1 presents the concepts identified and their relationship, further explained as follows:

The **human** being has the capacity to feel **emotions**, which involves and intertwines **cognition**, **senses**, **perception**, and **sensorimotor** aspects, that are triggered in sociocultural environments. In emotional interaction with two or more people, the **emotional contagion** is produced essentially by unconsciously mimicking and **synchronizing** with others' emotions.

In these interactions, human express their emotions through their **body expressions** in facial, psychological, and neurological expressions [10]. These expressions can demand external bodily changes, for instance, in **facial expressions**, body movements, and vocal tone, among others. Besides, it involves **neuro-physiological expressions** where electrical **brain waves** are dissipated by the brain through the autonomic nervous system, involving various bodily functions, including the cardiovascular system, affecting **heart rate**. Different emotional states are associated with distinct patterns of brain activity, which can be related to corresponding changes in heart rate.

Digital technologies like the Electroencephalogram (**EEG**) [26][4][45][67][29][32][43][56][48][47][30][66][62] are used to measure brain wave signals, and the Electrocardiogram (**ECG**) [42][65][52][53] is used to measure the heart rate signals. The Fourier Transform (**FT**) [34][39] technique is used to analyze the wavelet signals, considering the wave frequency and amplitude. Artificial Intelligence (**AI**)[4] is being employed to study neurophysiological information, which involves brain waves and heart rate signals. Several techniques are being investigated in the AI field. For instance, **Machine Learning**, in particular, the Support Vector Machine (**SVM**) algorithm is used mainly in studies due to its high accuracy in classifying and identifying patterns [26][30][47][48][36].

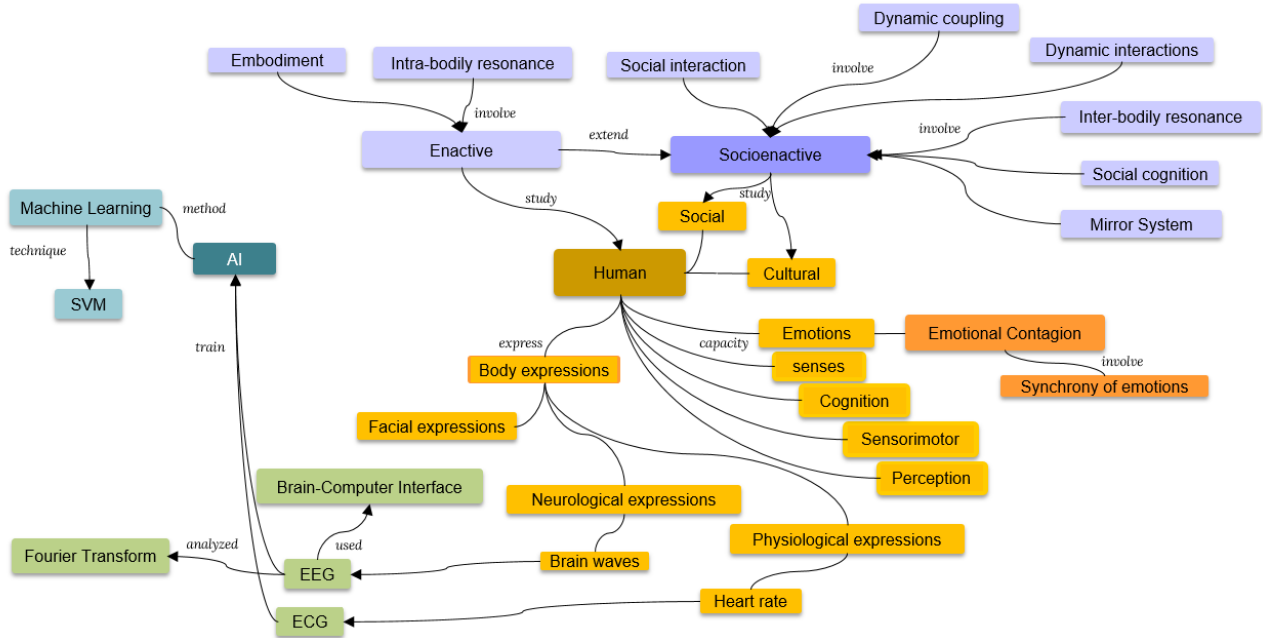


Figure 1: Conceptual map involving socioenactive, AI, and emotional contagion.

Despite the existence of technologies that study the human body through its neurophysiological information, it is not enough to understand the phenomena that occur inside and outside the human body. The enactive approach [60] [17] studies this phenomenology through the concepts the **intra-bodily resonance**, **embodiment** [16][15], and the **mirror system**[14]. When it is expanded to the social environment shaped by people, physical objects, and computational systems, the socioenactive approach takes place [3][2]. In this context, the concepts of **dynamic coupling**, **dynamic interactions**, **inter-bodily resonance**, and **social cognition** emerge. In the following, we delve deeper into the description and explanation of these concepts.

## 2.1 Enactive

The concept of enaction was incorporated into the field of information systems by offering new ways of interaction and user involvement with systems [31]. The enactive perspective posits that our mind, body, and the world are inseparable, engaging in constant and dynamic interaction [16] [61]. Human learning comes through interaction with objects and events in the world. Based on these interactions, humans understand the functionalities offered by such objects and events [31]. Considering this perspective, enactive systems involve the development of new technologies that allow a more physical and immersive modality of interaction between people and computational systems [31]. In enactive system approaches, human and technological processes are dynamically coupled, that is, there is a dynamic mind-technology embodiment [61].

**Embodiment** involves dynamic processes enabling embodied activity [60] [61]. It involves continuous and complex dynamic systems with feedback loops that have both external and internal orbits [27], which reshape, rewire, and remodel ([35], p. 55) the brain and body. On such a view, action does not play a secondary role to perception and cognition. Instead, action is what enables perception and cognition [60].

**Perception** is not about building internal representations that mirror an objective reality. It is

about how we actively explore and interact with our environment to make sense of it in a way that is meaningful for our actions and social lives. Perception is not conceived as the transmission of information, but more as an exploration of the world by various means. In this perception process, **senses** are not viewed as passive channels that simply transmit information from the environment to a detached brain. They are understood as active and embodied modes of engaging with the world, fundamentally intertwined with our actions and social interactions [61] [15].

In this process, **cognition** occurs in directed interaction between the body and the world it inhabits [61]. Cognition moves beyond the traditional view of it as solely an internal process of an individual brain representing the world [61]. Instead, it emphasizes that cognition is an embodied process that is fundamentally shaped by social interactions and cultural contexts. Cognition is a dynamic and emergent phenomenon that arises from the ongoing interaction between an organism and its environment [14][40]. It means our experiences are shaped by our actions and interactions with the world, rather than being pre-determined or solely residing within our brains [61].

Knowledge is constructed through sensorimotor interactions with the environment and co-constructed among living species through meaningful interactions with each other [61]. The **sensorimotor** capacity is involved in experiencing the world, arising from mutual interaction between the sensorimotor capacities of an organism and its environment. It states that an organism's environment is shaped by the active engagement of that organism's sensorimotor processes. This view emphasizes the dynamic interplay between sensory and motor activity in an organism's interaction with its environment [61]. The enactivism approach highlights that our experience of the world is not a passive reception of stimuli, but an active process shaped by our movement and interaction with the environment [61].

**Emotions** are not simply "felt" in the mind. They are manifested in actions and bodily changes and understood as dynamic processes that arise from interactions between individuals and their environment. The enactive approach to emotion emphasizes the role of embodied experience in understanding emotional phenomena [15] [40] [7].

## 2.2 Socioenactive

The socioenactive approach extends the concept of enactive systems by emphasizing the role of social and cultural values. The concepts that emerge from this context are Social interaction, Dynamic coupling, Dynamic interactions, Interbodily resonance, Social cognition, and the Mirror system.

**Culture** appears that seemingly natural experience is thoroughly intertwined with sociocultural realities [59]. The social experience involves the reality we share, and in which we find ourselves, is neither a world that exists independently of us, nor a socially shared way of representing such a pre-given world, but a world itself brought forth by our ways of communicating and our joint actions [59].

In **Social interaction**, dynamics in constituting individual and intersubjective capacities are involved. We genuinely have relationships with others; we are not independent but interdependent. We are living in an increasingly interconnected world [12] [15] [40].

**Dynamic interaction** is not limited to momentary state features and relations. It involves states and behaviors that exhibit long-term temporal or spatial correlations [12]. In interactions, the human body involves complex systems, and the internal interactions of these systems are not fixed and are subject to change over time without explicit direction [15]. The boundaries of systems are determined by complex interactions that involve phenomena [40].

**Social cognition** is how humans engage with each other in unique ways [58] [12]. They create and transmit new knowledge and practices, which are at the heart of cultural group formation

and transgenerational learning [15] [40]. For instance, infants, before they communicate through language, they engage with others nonlinguistically, and these communicative exchanges are meaningful because they entail a social-cognitive understanding of what others intend to bring across and make of one's communication.

The **Mirror system** is activated no matter whether the action is executed by the self or perceived as something done by the other. Indeed, a time series of mirror neuron firing could therefore involve an indistinguishable mixture of self- and other-generated activity [40]. Mirror neuron activation does not depend on reciprocal interaction; one individual's passive observation of another's action is sufficient as a trigger [16].

The **inter-bodily resonance** is a mechanism that involves internal and relational activities from more than one person. It consists of all kinds of activity crisscrossing the brains, bodies, and environment of two or more people [16]. For instance, seeing an angry face triggers an automatic mirroring of that expression, which in turn evokes the feeling of anger within oneself. This internal reaction is then outwardly expressed, becoming a perceived impression for the other person, thus enabling interbodily resonance. This rapid, ongoing exchange of expressions and reactions creates an autonomous, dynamic system connecting both individuals through reciprocal movements and feelings.

Considering the digital technological world that is embedded in social environments, the socioenactive approach refers to a dynamic and seamless interaction between a group of individuals and technology, where social, physical, and digital dimensions shape the experience. Essentially, socioenactive systems consider how digital technology and social dynamics influence each other, and how individuals' bodily experiences and social interactions within the system contribute to the overall experience. Human interactions are always situated within a social context, influenced by shared norms, values, language, and cultural practices. These socio-cultural elements significantly shape how humans interact with technology and how they interpret their experiences. The socioenactive approach involves a dynamic coupling between three dimensions:

- **Social world:** This includes the people involved, their relationships, communication, collaboration, and the broader social context.
- **Physical world:** It involves physical objects, technological artifacts, and natural elements.
- **Digital world:** This refers to computational systems, code, data, and virtual elements we interact with.

From this dynamic interplay between the social, physical, and digital realms, new phenomena emerge, such as emotion contagion. Socioenactive approaches aim to understand how these emergent properties arise from the interactions within these coupled systems. In the context of Human-Computer Interaction, socioenactive perspectives are particularly relevant for understanding how humans interact with increasingly complex and pervasive digital technologies. It moves beyond a simple view of a person interacting with a tool to consider the richer, embodied, and socially situated nature of these interactions. This includes considering emotions, cultural values, and the physical presence of individuals. In essence, socioenactive suggests that our experiences and understanding, especially when interacting with digital technology, are not just individual cognitive processes but are actively shaped by our bodies, the physical environment, the digital tools we use, and the social interactions we have with others.

Figure 2 presents the dimensions of socioenactive systems and their relationships.

The social world is coupled to the digital world through physical mediation. This means that things (physical) are perceived and acted upon in the social world. Digital is composed of compu-

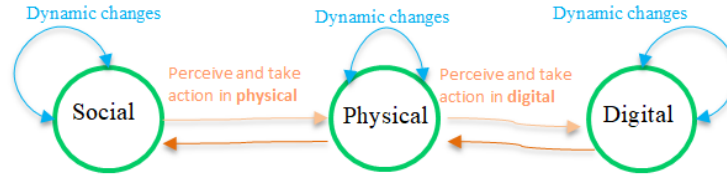


Figure 2: Socioenactive systems dimensions [2]

tational representations coupled to the physical world. Furthermore, it is essential to emphasize that the system is grounded in the physical world, considering the human body [55].

The three dimensions work in a loop; one dimension feeds back to another for its performance. The socioenactive cycle is characterized by the autonomy of the three dimensions based on social feedback [55]. In social interactions, a circular relationship is built between the brain, the organism, and the social environment in these three dimensions. Likewise, it is involved in embodied perception, sensorimotor coupling, social cognition, emotions, among others, having the brain as a constituent of the system.

### 2.3 Artificial Intelligence (AI)

Studies in AI are applied to facial expression analysis, speech emotion recognition, and the analysis of emotions in text, among other areas. Within the neuroscientific domain, emotions have been studied in the field of AI involving techniques for emotion recognition [25]. These techniques are based on neurological and/or physiological models. Generally, signal processing methodology identifies patterns in neural and physical manifestations of internal states [4]. Existing studies have found that visual and auditory modalities dominate most emotion recognition research [25].

The cerebral cortex is typically separated into four areas, each of which performs a distinct function. The prefrontal cortex (PFC) has been proven to be the most closely connected with emotion in studies [25]. The brain works by transferring electrical signals between neurons. One method to study the brain’s electrical activity is to record the potential of the scalp caused by brain activity. The signal that is recorded is called an electroencephalogram (EEG). EEG is one of the most efficient methods for monitoring brain activity, often referred to as brain waves [25].

The changes in emotion can be understood by studying the EEG signals [4]. The EEG does not just represent the electrical activity of a single neuron, but rather the electrical activity of a group of neurons in the brain area where the EEG measuring electrode is positioned. As a result, the EEG signal includes a wealth of useful and meaningful neurophysiological information. In medicine, EEG signal classification, processing, and analysis provide an objective basis for detecting certain diseases [63]. In neuroengineering, people with disabilities can use EEG signals produced by motion imagery or the mind to control wheelchairs or robotic limbs [21]. This is a research topic known as the Brain-Computer Interface (BCI). Analysis and processing of EEG signals are always problematic in brain research due to the non-stationarity of EEG data and the numerous environmental influences [25] [67].

#### 2.3.1 EEG signals

The EEG signal is a direct representation of brain activity, helping to study physiological phenomena of the human brain [44][29][67]. EEG signals are classified into five categories based on the

variation in frequency bands: delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (> 30 Hz).

- **Delta** waves usually occur in the frontal cortex; they are usually detected in an unconscious state of lack of oxygen, deep, dreamless sleep, or being anaesthetized. The wave would vanish in an adult who is awake and alert [39].
- **Theta** waves usually appear in the parietal and temporal lobes. They are associated with a relaxation state and working memory load. Theta waves on the frontal midline will rise when positive emotions are evoked [44].
- **Alpha** waves mainly occur in the occipital lobe and parietal lobe, they can be detected in the resting state with eyes closed. External stimuli, such as visual or auditory stimuli, or when individuals are engaged in mental activity, can cause alpha waves to disappear. They have more oscillatory energy than beta and gamma waves in both positive and negative emotions [39].
- **Beta** waves are typically only observed in the frontal lobe; however, when one is contemplating, the beta wave emerges in a variety of locations. They happen when a person's mind is very active and focused. Alpha waves dominate the cerebral cortex while the human body is relaxed, and the beta rhythm gradually fades as emotional activity increases. Under tension/stress/strain, the Alpha wave's amplitude decreases while the Beta frequency increases, and the Alpha wave progressively turns into a Beta wave. When the cerebral cortex appears to be in a beta state, it typically indicates that it is excited [67],[29].
- **Gamma** waves are found with different sensory and non-sensory cortical networks. They are associated with high-level brain cognitive tasks and functions, such as information reception, processing, integration, transmission, and feedback in the brainstem, as well as activities that require a lot of attention (concentration). They are frequently observed during the process of multimodal sensory perception [29],[67].

### 2.3.2 EEG Signals in Emotion Recognition

Emotions can be expressed verbally, such as through well-known words, or non-verbally, through voice tone, facial expressions, and physiological changes in the nervous system. Because facial expressions and voice can be faked or are not considered reliable indicators of a specific emotion, they are not trustworthy predictors of emotion. Because a person has no control over the physiological signals, they are more precise.

The fundamental sources of emotion in our bodies are physiological changes. Physiological changes can be categorized into two main groups: those that affect the Central Nervous System (CNS) and those that impact the Peripheral Nervous System (PNS) [21]. The spinal cord and brain make up the CNS. The changes in electrical activity involve changes in the physiological state of the body.

The electroencephalogram (EEG) is a test that measures electrical changes in the brain. EEG is described as alternating-type electrical activity recorded from the surface of the scalp using electrodes [49] [42]. EEG contains a wealth of useful information on the brain's neurophysiological states [62]. It is a particularly valuable tool for understanding human emotional states [41].

The EEG signals can be analyzed by combining data from the time and frequency domains. The ability to collect time-varying and non-stationary signals, which can be used to characterize different emotional states, is made possible by time-frequency domain characteristics [66]. The

Fourier Transform [34] is the method of time–frequency analysis that is most frequently utilized [49] [39].

### 2.3.3 Machine Learning

Machine Learning (ML) is a technique broadly used in emotion recognition [66]. This technique involves algorithms that categorize various emotional states based on EEG data. There are ML methods that significantly impact classification or prediction results [49]. Specifically, the Support Vector Machine (SVM) is a method that categorizes data into distinct groups, using discriminant hyperplanes to identify classes. The SVM is the most popular classifier for emotion recognition based on physiological signals [32].

## 2.4 Emotional Contagion Phenomenon

Emotion contagion is a form of social interaction in which our emotions are spontaneously spread from one person to another [22], and our perception and actions are inherently connected [15]. The phenomenon occurs when humans synchronize their own emotions with those expressed by others around them. When people unconsciously mirror their companions’ emotional expressions, they come to feel reflections of their companions’ emotions; at this time, the mirror system is activated [15].

The mirror system involves neurons, which phenomenologically respond to contagion based on embodied perception or intercorporeality (we always already perceive others as being of our own kind) [15]. According to Rizzolatti and Gallese [46] [18] [5] mirror neurons are fired when a person acts and when he/she observe the same action performed by others. These neurons provide the physiological mechanism for perception-action coupling, which helps to understand the actions of other people and to learn new skills by imitation [18].

Neuroscientific studies have identified that specialized regions of our brain are involved with mirror neurons [63]. Neurons in the superior temporal lobe (sulcus) are involved in the interpretation of animate movement and in cases of “contagion” through the laughter or crying of others [40]. Regions of the sensory cortex in the parietal lobe play an essential role in empathic sensations [40]. These neurons are involved in the physiological functioning of the body, and they are not independent but interdependent [46] [18] [5] [15].

## 3 Related Studies: Methodology and Results

This section aims to conduct a systematic literature review to obtain and evaluate related studies. Section 3.1 presents the methodology applied to perform the literature review. Section 3.2 reports on the results.

### 3.1 Methodology

Our literature review focuses on answering the research question (RQ), drawing on publications from the four main academic libraries in the field of Computer Science: ACM, IEEE, Springer, and Scopus. We were guided by the procedure outlined by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) protocol of three phases: identification, screening, and included [38]. We used the JabRef and Excel applications as resources to manage the literature review records.

We initially conducted an automated search for studies in the defined scientific research databases, using a search string that encompassed concepts related to the research questions and considered the inclusion and exclusion criteria. After this step, we carried out the screening process, which involved analyzing the abstract and title of the initial selection to identify studies most closely related to the objectives of our literature review.

Using the combination of keywords, we searched for representative investigations that involve the specified keywords.

For the final selection, we grouped the studies considering the keyword combination. We reviewed some of the selected articles, conducting a detailed reading of the main articles related to the core concepts (socioenactive, enactive, emotion contagion, and AI), identifying relevant aspects for discussion. Finally, we developed a quality analysis of these main articles and their relevance.

**Search Strategy.** We defined a search string composed of relevant terms to the research questions. The term is related to the concepts of the socioenactive, enactive, AI, and emotional contagion. The search string for the automatic search in the four digital libraries was built as follows:

1. *socioenactive OR enactive*
2. *AI OR “Artificial Intelligence”*
3. *“emotional contagion” OR “emotions”*

The “**AND**” boolean operator joined all three main parts. This means that an article had to include the combination of these terms to be retrieved. (1) AND (2) AND (3)

#### **Inclusion (IC) and exclusion (EC) criteria.**

- IC1 Document in the field of computer science.
- IC2 Document in English, Portuguese, or Spanish.
- IC3 Document is an indexed scientific journal article, a book chapter, or a paper published in the proceedings of a scientific conference.
- IC4 Document is involved with the topic.
- EC1 Document classified as a short paper.

In our first round of the literature review, we found studies focused more on a specific area, for instance, socioenactive, but without considering the other fundamental keywords (AI and emotional contagion).

Our search strategy was refined to split our search based on the main keywords: socioenactive, enactive, AI, emotional contagion, and emotions. We made a combination of these five keywords. Using math, we employed the combination formula “ $nCr = n! / (r! * (n-r)!)$ ”, and combined the 5 keywords in groups of two, where  $n = 5$  is the number of keywords and  $r = 2$  is the number of elements to combine. The result of the keyword combination was the following:

- *socioenactive AND enactive*
- *socioenactive AND emotional contagion*
- *socioenactive AND emotion*

- *socioenactive AND AI*
- *enactive AND emotional contagion*
- *enactive AND emotion*
- *enactive AND AI*
- *emotional contagion AND emotion*
- *emotional contagion AND AI*
- *emotion AND AI*

### 3.2 Results

A total of 4948 studies were identified in the initial selection set to be analyzed. Of this selection, 258 studies are from the ACM database, 825 are from the IEEE Xplore, 1241 works are from the Springer database, and 2624 from the Scopus database.

We conducted a screening considering the inclusion/exclusion criteria IC1, IC2, IC3, IC4, and EC1. In our selection, we reached 1454 studies for our analysis. We analyzed and organized these investigations considering the keywords, and filtered them considering the main keywords, and focused on the concepts involved in the conceptual map for eligibility.

The final result included 7 articles, which we analyzed in details. Figure 3 presents the results of the selection process.

To gain an overview of the studies, starting from the 1,454 studies identified in the screening process, we created a graph with 5 vertices; every vertex is connected to every other vertex by a single edge. The formula employed for calculating the number of edges in the complete graph is  $n(n-1)/2$ , where  $n$  is the number of vertices. In this case,  $5(5-1)/2 = 5*4/2 = 10$ .

After shaping the graph with the 5 vertices, we assigned a concept/keyword to each vertex. Each edge represents the quantity of studies involving the keywords. Through the graph illustration 4, we obtain a quantitative view of the studies concerned with each research field.

The results showed that there are numerous studies (1,243) on emotions and AI, 49 studies on enactive AI, and 23 studies on enactive and emotional AI. The results clearly show there are a few studies involving socioenactive, AI, and emotion contagion. The literature review showed 3 studies concerning the emotional contagion and AI, 3 studies concerning socioenactive and emotion, 1 study involved socioenactive and AI. There are no studies involving socioenactive and emotion contagion, enactive and emotion contagion. This finding opens the door to new studies and unexplored research areas.

In the following, we provide a detailed analysis of the included studies.

### 3.3 Socioenactive and Emotion

Valderlei *et al.* [54] (S1 in Table 1) studied the socioenactive approach including emotions. In their research, a socioenactive system was studied, incorporating ubiquitous and wearable technologies. The Aquarela Virtual system [13], developed to explore socio-enactive aspects during the pandemic, was extended to include objects that can be worn on the body and in the environment. An emotion box was used to allow participants to express their emotions by pressing buttons corresponding to specific emotions. Considering the emotional aspect, a light display was used to enhance the ambiance with color. A TV was also used to display a mosaic of colors, considering the

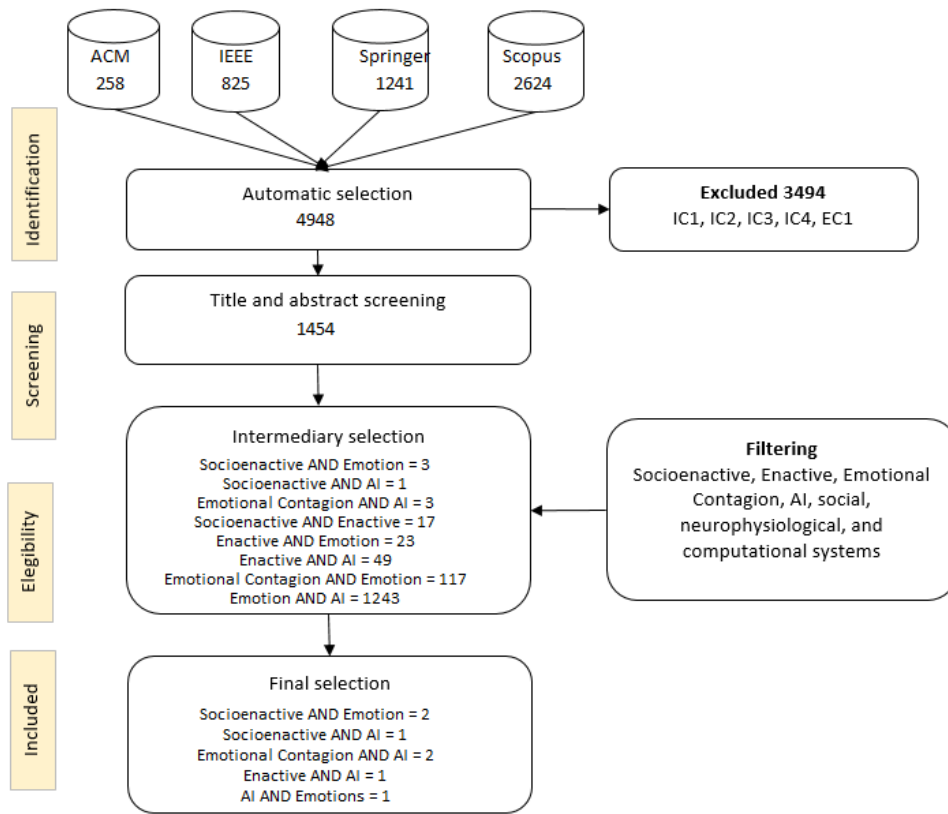


Figure 3: PRISMA protocol results of the literature review.

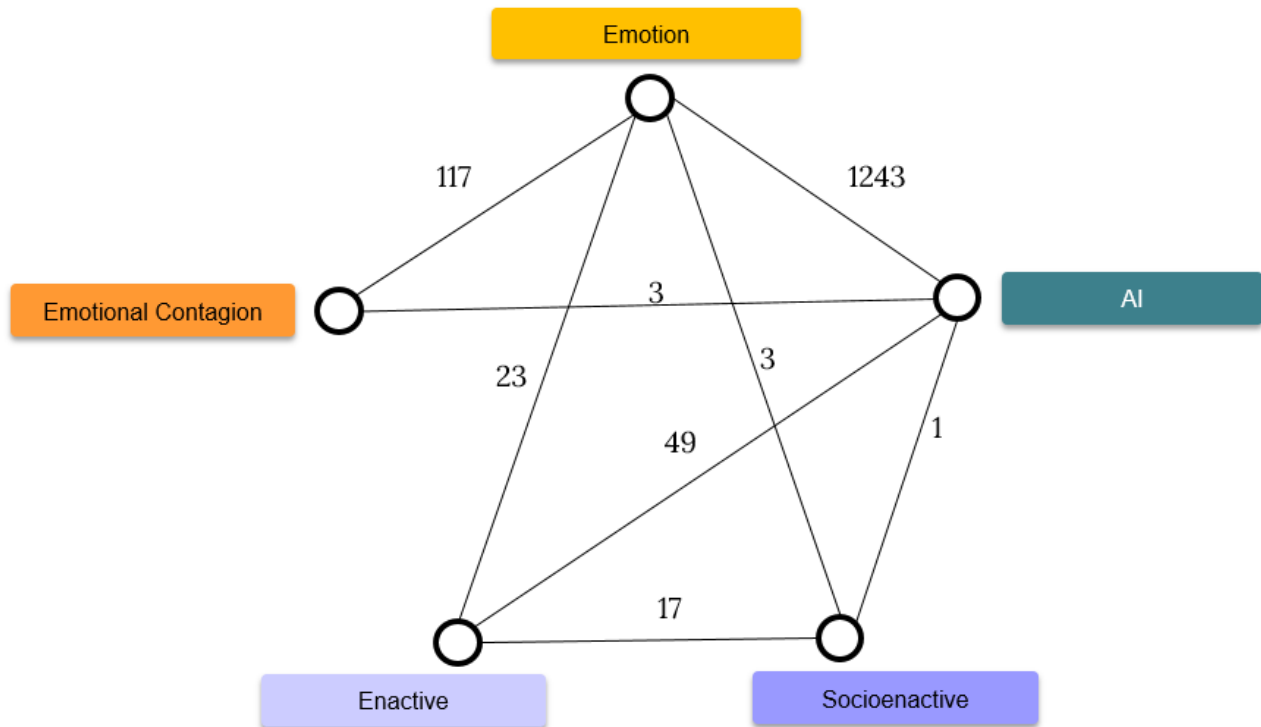


Figure 4: Analysis of identified studies in the field of socioenactive, enactive, emotions, emotional contagion, and AI.

participant’s emotions. As a wearable technology, a glove was used to collect participants’ heart rate information. The objects placed in the space brought interactivity among the participants, promoting the exposure of feelings, and also allowed everyone to visualize emotional diversity. This study provides insight into how physical objects can be utilized for interactions and the transmission of emotions. The socioenactive approach is examined in this work, exploring how physiological information (specifically, heart rate) can be utilized to foster socio-emotional interactions.

Valderlei *et al.* [8] (S2 in Table 1) presented a socioenactive system that connects objects embedded with ubiquitous technology to work together with people. The system involved a network of objects (a bear, monkey, owl, and Christmas tree) with technological skills of sensing or acting in that environment. The Christmas tree with LEDs responds to children’s hugs of the Pets (teddy bear and monkey). The tree light levels turn on based on the number of hugs received by the teddy bears. When all the lights on the Christmas tree came on, a picture of the Christmas tree was displayed on a TV screen, and a Christmas sound was played in the background. The teddies, during the hugs, played sounds of emotions. Furthermore, an owl as a teddy was in charge of taking pictures of the children’s hugs with the teddies. This study employed the socioactive approach and examined emotions in social interactions.

These two studies investigated the socioenactive approach in Human-Computer Interactions, considering social and emotional aspects.

### 3.4 Socioenactive and AI

The study of Gonçalves *et al.* [19] (S3 in Table 1) presented a proposal for facial recognition applied to a socioenative system. Their work presented an architecture of a socioenative system with AI. The AI in the system is used to recognize emotional states in participants' faces. The SVM algorithm was used as an AI technique to recognize facial emotional patterns. Despite this study involving AI and socioenative systems, it was still exploratory. Physiological aspects are explored through the use of gloves that would have the capacity to gather physiological data in the socioenative system.

### 3.5 Enactive and AI

The study by Kaipainen *et al.* [31] (S4 in Table 1) investigated the enactive approach, demonstrating an enactive system based on human psychophysiological reactions. Instead of the standard explicit interface, there is an implicit connecting surface, based on unconscious psycho-physiological responses. The aim is not only to point out an analytic approach to existing media systems but also to develop radically novel media concepts implied by the enactive systems. The system analyzes a person's psychophysiological expressions to create a film. The system was built with minimalist aspects and uses facial electromyography (EMG), heart rate (HR), and electrodermal activity (EDA) to measure emotional expressions. The system assembles the film based on psychophysiological expressions and a spatial ontology. The ontology contains a repertoire with notations and some automated analysis. This study aimed to demonstrate how unconscious interaction can occur in Human-Computer Interaction (HCI). Despite being interesting due to its novel ways of interaction, using humans' neurophysiological information, it does not adequately tackle the social and cultural aspects involved with more than two people.

### 3.6 AI and Emotions

Wang *et al.* [64] (S7 in Table 1), involved the human-AI interaction promoted by BCI and a neurohaptic interface. The system was designed to connect two remote individuals over the internet. The two people wear a BCI (based on EEG) device and a haptic armband. When the system recognizes an emotion from one person, such as 'feelings of missing someone,' it transmits commands to the haptic armband of the remote person. The system displays the image of the person who transmitted the "missing you" signals to the remote person on a screen. This study enables human-AI emotional interactions; neurophysiological aspects are examined through the use of brain waves (EEG) and muscle movements (electromyography). The AI was used to recognize emotions in brain waves collected by an EEG device. This study involve the social and emotional aspect; however, the emotional contagion aspect is not tackled.

The majority of the studies we analyzed in this literature review involved AI and emotions, focused on the technical aspects of algorithms and their accuracy in emotion recognition, without exploring the social aspects, and even more, the emotional contagion and socioactive aspects involved in socio-emotional interactions.

### 3.7 Emotional Contagion and AI

The work of Munjia *et al.* [33] (S5 in Table 1) investigated the emotional contagion through a system that perceives human emotions based on physiological signals. Their study utilized wearable equipment to measure a person's emotions based on physiological signals. An emotional contagion system is presented, which could develop robotic emotions based on human emotional interactions.

Physiological emotion recognition was studied in the context of digital robotic sensory generation. The system influences the senses to generate perception and establishes an emotional transition for developing a robotic (avatar) emotion. Physiological signals were collected through a wearable wrist strap that records electrocardiogram (ECG), electromyogram (EMG), and galvanic skin response (GSR) signals. The system processed this information using the Fast Fourier Transform (FFT) and Support Vector Regression (SVR), an extension of the Support Vector Machine (SVM) algorithm. The results showed that the emotional contagion system performed better in single-user interactive situations or with multiple users.

The work of [24] (S6 in Table 1) studied the emotional contagion through the co-creation process of emotions through the use of a wearable device. In their study, self-reports were used to measure levels of emotional contagion. Additionally, it utilized biometric technology to enable the analysis of emotional fluctuations over time. It allows the measurement of co-creation of emotions using a wearable device and AI. The pulse rate was converted into valence as a positive–negative emotion. Their work proposed a system that involved the triangulation and integration of biometric, observational, and self-report data. The proposed system was verified to measure the co-creation of pair and group emotions.

Despite these studies addressing emotional contagion and AI, they do not tackle the phenomena that occur in humans’ brains and bodies within their environments, considering the socioenactive approach.

Table 1 presents and organizes the investigated studies in our literature review, considering the keywords (socioenactive, enactive, emotions, emotional contagion, and AI) and the concepts involved in the conceptual map, which involve the neurophysiological concept. The analysis yielded gaps that have not been explored for future studies.

The studies S1 and S2 address the topic of socioenactive and emotional approach. The S3 addresses the study of socioenactive and AI. The study S4 addresses the enactive and AI field. The studies S7 address the field of AI and emotion. The studies S5 and S6 address the emotional contagion and AI. Each of these studies contributes to the understanding of the main topics.

Each of these studies used its own methodology, however, when their topics are related, the methodology could be similar. For instance, the studies S3 and S7 used the SVM technique as a method of Machine Learning in AI.

## 4 Discussion

The socioenactive approach is a novel perspective in human-computer interactions that enables us to understand phenomena involving the human brain, body, and the surrounding space. It consists of studying the senses, perception, sensorimotor skills, cognition, emotions, and other aspects related to interaction with technology. According to Valderlei *et al.* [8], there is a need for deep studies regarding the core concepts of the socioenactive approach. Mendez *et al.* [37] underlined that it is necessary to conduct profound studies regarding design considerations that involve the physical body in the interaction of humans and computers in socioenactive systems.

In recent years, socioenactive systems have been studied and explored in several fields, including intersubjectivity [3], embodied creativity [6], imagination [11], among others. However, there are still gaps that should be covered by new research considering AI in human’s neurophysiological information in environments where the emotional contagion phenomenon occurs.

The theoretical background gave us the main concepts involved with socioenactive, AI, and emotional contagion approaches.

We could understand that humans’ neurological information could be measured using an elec-

ID	Year	Title	Socioenactive	Enactive	Emotions	EmotionContagion	AI	Physiological	Neurological
S4	2011	Enactive systems and enactive media: embodied human-machine coupling beyond interfaces. (Kaipainen <i>et al.</i> [31]).		X			X	X	
S5	2018	Emotional contagion system by perceiving human emotion based on physiological signals. (Li <i>et al.</i> [33])				X	X	X	
S7	2020	Jean Joseph v2. 0 (REmotion): make remote emotion touchable, seeable and thinkable by direct brain-to-brain telepathy neurohaptic interface empowered by generative adversarial network (Wang <i>et al.</i> [64])			X		X	X	X
S3	2021	Design of Socioenactive Systems Based on Physiological Sensors and Robot Behavior in Educational Environments (Goncalves <i>et al.</i> [19]).	X	X	X		X	X	
S2	2022	Building a space for the human in IoT: Contributions of a design process (Silva <i>et al.</i> [8]).	X	X	X				
S1	2023	Design socialmente consciente de espaos humanos com Internet das coisas (Silva <i>et al.</i> [54]).	X	X	X			X	
S6	2024	Beyond Empathy: Unveiling the Co-Creation Process of Emotions through a Wearable Device (Ho <i>et al.</i> [24])				X	X	X	
	2025	This work	X	X	X	X	X	X	X

Table 1: Related studies involved with the concepts of the socioenactive approach, emotional contagion, and AI.

troencephalogram, which measures the electrical activity of the brain. Additionally, there are areas in the brain that are more involved in electrical activity when we experience emotions. The human being possesses a mirror system, which is involved in emotional contagion interactions within social environments.

Answering the RQ: What is the state of the art of socioenactive systems involving AI and the emotional contagion phenomenon? Through the theoretical background in Section 2, we explained the concepts involved in socioenactive, AI, and emotional contagion. The concepts described in Section 2 were obtained from books and articles related to the investigated research topics. We found concepts associated with the socioenactive approach, which underscore the social aspect. For instance, enactivism authors discussed social interaction, dynamic coupling, dynamic interaction, inter-bodily resonance, and social cognition. However, due to the social aspect being involved with concepts, they should be discussed in the socioenactive approach.

The literature review revealed a substantial number of studies on AI and emotion (1243). However, few studies have tackled the emotional contagion and AI (3), and no studies have addressed

the socioactive approach in emotional contagion interactions. Additionally, we identified that one of the most widely used and well-known techniques in AI is the support vector machine (SVM) for emotion recognition.

Each of the related articles surveyed offered a different and complementary perspective on their field, enriching the understanding of the topics involved in the studies. The surveyed articles provided us with essential sources of additional information, including references to other relevant studies and theories. The investigated studies helped us identify how the primary research relates to other research, allowing us to establish connections and build knowledge networks.

## 5 Conclusion

This study presented a background of the related concepts involving socioactive systems. We conducted a literature review to explore the connections between socioactive, AI, and emotion contagion, aiming to gain a deeper understanding of these fields. Our analysis demonstrated the existence of studies regarding socioactive approach and emotion. Our results indicate a gap in studies concerning emotional contagion and the socioactive approach, although few investigations have addressed AI and the socioactive approach. These gaps and weaknesses in the literature open avenues for future studies.

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