Imagination on Interactive Installations: A Systematic Literature Review

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Abstract: Imagination plays a key role in human development as a natural process between the individual and their surroundings, including environmental possibilities. Today, these surroundings often include ubiquitous and pervasive technologies that enable new interaction possibilities. Although imagination is an important aspect in the theory of enactivism, it remains unclear whether it has been investigated within the context of interactive installations, ubiquitous computing, or other kind of application that emphasizes embodiment. This article presents a systematic literature review investigating if and how imagination has been explored in ubiquitous scenarios of interactive installations. We found that ubiquitous technologies can play an important role in enabling imagination in interactive installations. There is, however, a need for more specific design and evaluation methods and theory adoption to support imagination in the design of interactive systems. On this need, we contribute with a research agenda for further study on this subject.

1 INTRODUCTION

Ubiquitous and pervasive technologies have become more and more common in our daily lives. Weiser (Weiser, 1991) refers to Ubiquitous Computing as deep and profound technologies which become seamless and disappear into everyday life. A complementary concept, pervasive computing is related to the omnipresence of computers within the environment while being invisible to the user (Hansmann et al., 2013). As a result of these approaches, ubiquitous and pervasive technologies can support users' goals without them having an explicit task to be accomplished through a user interface. In these cases, an user does not necessarily have an explicit set of controls to directly interact with the system. The user actually interacts with the environment, in which the computational technology is transparently embedded.

In this context, our research is interested in the concept of enactive, socioenactive, and similar systems that also emphasize some kind of embodiment. Supported by the concept of embodiment, Kaipainen *et al.* (2011) defined enactive systems as computational systems constituted by human and technological processes dynamically connected through a coupling of body and technology (Kaipainen et al., 2011). An enactive system is neither objective-oriented nor all human actions it detects and acts upon are conscious, allowing, for instance, interactions based on psycho-physiological data feedback (*e.g.*, facial expressions, heart rate, *etc.*). In its turn, the theoretical and practical concept of socioenactive systems has been investigated to develop a conceptual framework for the design of enactive systems that expand upon individual interactions and mediate actions and perceptions in the physical environment (Baranauskas et al., 2021). It can be said that socioenactive systems emphasize social and cultural aspects.

Within the theory of enaction (Varela et al., 1993), which is the foundation for both enactive and socioenactive systems, the concept of perceptually guided action contains an inherent aspect of imagination. According to Gallagher (2017) , the enactivist view of imagination is about affordances (Gallagher, 2017), which can be interpreted as opportunities for interaction that arise from the relationship between someone and an object, be it abstract or concrete (Gib-

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son, 1979, p.172). Imagination is not considered as a pre-determined state within the individual's organism, risen from a history of interactional activities to now cause a new action. Rather, it is a constituent part of a coordinating process that adds experiences with the broad context in which the individual is involved and with the possibilities of future activities available. Our understanding of imagination is aligned with Gallagher's, as we see objects or events in terms of what possibilities they offer, we think of this phenomenon as imagination in action.

Returning to the domain of computational systems, when enactive and socioenactive systems emphasize an approach that is not objective-oriented or pre-determined, imagination, through active discovery, becomes an important subject of investigation. However, although imagination is an important aspect in the theory of enactivism, it remains unclear whether it has been investigated within the context of enactive, socioenactive systems, or any other kind of system that emphasizes embodiment. Furthermore, we could not find preview literature reviews published before the development of our study which investigated how imagination has been approached in these kind of systems.

In this study, we present an original systematic literature review that investigates how imagination has been addressed in the context of ubiquitous, pervasive, enactive, socioenactive systems, *etc.* We address how these interactive systems stimulate or support the imagination of their users. As an instance of ubiquitous, enactive, embodied systems, *etc.*, our systematic literature review investigated the specific domain of interactive installations. This domain is appropriate for our investigation because interactive installations and their exhibition spaces are often in the *avant-garde* of interaction design by their constant experimental use of technology and envision of novel, unconventional interaction approaches. With our systematic literature review, we aim at understanding how imagination has been approached in interactive installations that are ubiquitous, enactive, socioenactive, embodied, *etc.* This includes an overview of which is the context and target audience; what technology is used; how does the interaction occur; how (or if) evaluation is conducted; and what different views of embodiment and imagination are found in literature. We expect that these contributions are useful to better understand and inform the design of such systems.

The remaining of this paper is organized as follows: Section 2 describes the methodology of our systematic literature review; Section 3 presents the main characteristics of the obtained results regarding to our investigation; Section 4 discusses our findings and indicates open challenges; lastly, Section 5 presents our conclusions and directions for future works.

2 REVIEW METHODOLOGY

Our systematic literature review methodology is based on the process proposed by Gough, Oliver, and Thomas (Gough et al., 2012). We chose to work based on how they present recommendations on systematic review processes without being restricted to a specific area of knowledge. The process began with the definition of the objective of the literature review. In particular, our study addresses how concepts such as enactment, socioenaction, imagination, and embodiment together with ubiquitous/pervasive technologies, are used in the context of interactive installations in exhibition spaces. Then, we defined a set of research questions (Section 2.1) and established a protocol (Section 2.2) with the formulation and conduction of a search strategy and a set of selection criteria. Finally, the process led us to the description of the characteristics of the selected studies (Section 2.3).

2.1 Research Questions

The research questions that guided our literature review reflect an effort to understand how imagination was approached in interactive installation settings in previous published works. The research questions addressed in this review are the following:

> **Research Question #1:** How do interactive installations based on ubiquitous and/or enactive technologies explore the concept of imagination?

This first question seeks to identify how theories and concepts related to imagination are put into practice in the context of interactive installations that use ubiquitous and enactive technologies. We answer this question by analyzing how the concept of imagination is approached in the selected studies.

> **Research Question #2:** How is the use of imagination evaluated in ubiquitous and/or enactive interactive installations?

This second research question aims to identify whether and which evaluation methods are used to assess the use of imagination in interactive installations. We answer this question by identifying which methods are used, what elements and aspects are evaluated, and how (or if) they are evaluated.

Research Question #3: How does embodiment help to explore human imagination in ubiquitous and/or enactive interactive installations?

The third research question is relevant to understand how aspects of embodiment contribute to explore imagination. We aim to comprehend to what extent the incorporated interaction contributes to the imaginative process. We answer this question by considering categories of embodiment and imagination from the selected studies. Our study analyzes how these categories are related to each other.

2.2 Review Protocol

The review protocol was based on the PRISMA flow diagram (Moher et al., 2009). Figure 1 presents the diagram with the steps conducted and maps the number of studies identified, screened, included, and excluded (including reasons for the exclusions). The main components of the review protocol are described in the following sections.

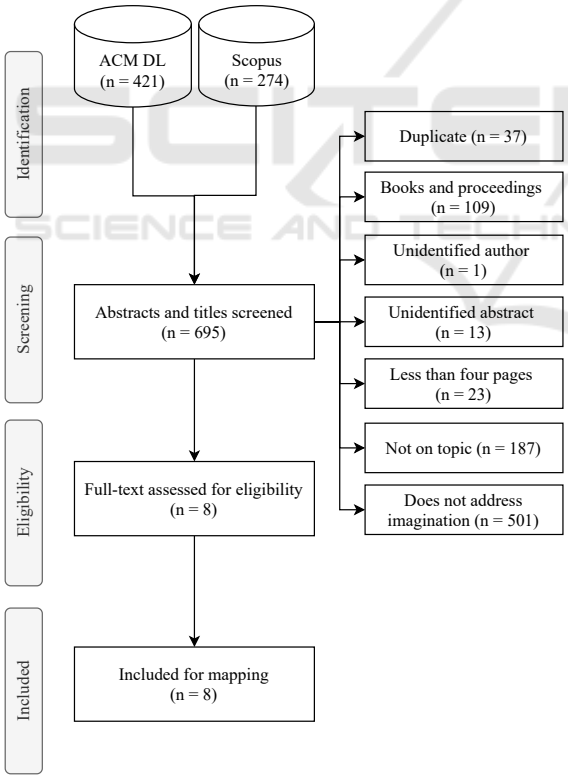

Figure 1: Search and selection flow diagram. Based on the PRISMA (Moher et al., 2009).

2.2.1 Search Strategy

We selected two digital sources to search for studies: the ACM Digital Library[1], with the search expanded to include the larger database known as the "ACM Guide to Computing Literature", and Scopus[2]. These sources were chosen because their main characteristic is their wide use and indexing in the Computer Science and Human-Computer Interaction (HCI) research areas.

On the basis of our research questions, we created a three-part search string. First, the string addresses concepts related to enaction. Then, the string restricts the search to the domain of interactive installations. Finally, the string screens the documents for our subject of research of imagination. Regarding imagination, we used the terms roleplay and storytelling because they refer to activities that spark the imagination; the first is about changing behavior to fulfill a role; the second regards creating narratives and telling stories. The term metaphor, in turn, was used because of the possibilities of establishing relationships of analogies between words, expressions and also objects, boosting the imagination for their creation. The search string was written as follows (later adapted to the specific syntax of each digital library searched):

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(ubiquitous OR pervasive OR
enactive OR embodied) AND
("interactive installation" OR "art
installation" OR "installation art"
OR "participatory performance")
AND (imagination OR roleplay OR
metaphor OR storytelling).
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2.2.2 Exclusion and Inclusion Criteria

We defined a set of exclusion and inclusion criteria to select the most suitable studies, presented in Table 1. After eliminating duplicated documents, the exclusion criterion EC1 was defined because we cannot properly evaluate documents that do not contain an identified author. The EC2 criterion was defined because with a large volume of studies as input, it would be almost impossible to read the entire papers for this selection phase. Exclusion criterion EC3 states that studies with three or fewer pages are considered short papers with still preliminary investigations, unlikely to contain sufficient and complete material to contribute to our research questions. The EC4 criterion expressed our interest in studies published as journal articles, conference proceedings papers, or book

[1]https://dl.acm.org/
[2]https://www.scopus.com/

chapters, presuming some form of peer review process before the publication. Finally, the EC5 exclusion criterion was related to our systematic review research questions, reiterating that any work that does not have the potential to contribute to generating answers to one of the research questions should be excluded.

Table 1: Selection (inclusion and exclusion) criteria.

Exclusion Criteria	Inclusion criteria
EC1: The document has no identified authorship.	**IC1**: The document presents an account of interactive installations or exhibition spaces as a central aspect.
EC2: The document has no identified abstract in the text.	**IC2**: The document presents concepts related to embodied cognition and/or related concepts (e.g., enaction, embodiment, etc.)
EC3: The document consists of three or fewer pages.	**IC3**: The document explores the proposal of imagination or roleplay in interactive digital tools.
EC4: The document is not an article published in an indexed scientific journal, or a book chapter, or a paper published in the proceedings of a scientific conference.	**IC4**: The document presents social aspects and/or interactions in the presented system.
EC5: The document diverges from the subjects of the research questions.	

Inclusion criteria IC1, IC2, IC3 and IC4 address specific topics of interest in our systematic literature review: interactive installations and exhibition spaces (IC1) as a central aspect; embodied cognition and related concepts (*e.g.*, enaction, embodiment,*etc.*) (IC2); imagination or enactment (IC3); and social aspects and/or social interactions (IC4). Selected studies should not satisfy any exclusion criteria, satisfy IC3, and at least IC1, IC2, or IC4. The need for IC3 is justified by the importance of the concept of imagination and related concepts in our literature review. For IC1, IC2, and IC4, although individually important, requiring all of them would be too restrictive, therefore one is enough.

2.2.3 Search and Screening

After formulating the search strategy and selection criteria, we applied our search string to the selected digital libraries, using full-text advanced search and limiting to entries published after the year 2010 (considered period of ten years to include more recent technologies). When necessary, the syntax of the search string was adjusted according to the specifics of each digital library without changing its logic. The search was carried out on May 19, 2021 and 695 studies were identified. The ACM Digital Library returned 421 results and Scopus returned 274 results. This step corresponds to the "identification" element from the flow chart of Figure 1. The retrieved records were exported in BibTeX format and we used the JabRef[3] to normalize them to be sorted according to our selection criteria.

In the initial screening phase, we excluded 37 duplicated entries, 1 entry with no identified author (EC1), 13 entries without identified abstract in the text (EC2), 23 entries with three or fewer pages (EC3), and 109 entries that were complete books or proceedings (EC4). To continue the screening phase, we exported the remaining JabRef entries to a spreadsheet for manual screening of titles and abstracts. We examined the studies addressing the inclusion criteria IC1, IC2, IC3, and IC4. A number of 187 studies were considered unrelated to the topic. They did not show clues towards contributing to our research questions and, therefore, were excluded. Furthermore, 501 studies did not meet our inclusion rule of meeting inclusion criteria IC3 and at least one more among IC1, IC2, and IC4. Thus, with strict application of the selection protocol, a total of 8 studies remained and and were included for further analysis. After reading the full-texts of the 8 remaining studies, all of them satisfied our inclusion criteria were considered eligible, resulting in 8 studies selected and included for review.

2.3 Analysis Procedure

The 8 selected full-texts were exhaustively read and analyzed. We proceeded by describing characteristics of these studies via two sets of questions we defined for this review. These questions were answered by the first author, but were also discussed and revised with the other authors. The first set concerns more general aspects of the studies aimed at providing an overview of their main characteristics, inquiring about the nature of the proposal, the social and physical context, and the target audience.

The second set of questions regard more specific aspects of the studies with relation to our research questions and objectives. They are either directly or indirectly related to how imagination is approached by inquiring about technologies, (social) interaction, evaluation, theoretical background, embodiment, and concept of imagination.

[3]https://www.jabref.org/

3 RESULTS

A total of 8 studies were selected in our systematic literature review. Each of the following sections present characteristics extracted from the selected studies.

In Section 3.2 we explore which and how technologies are employed in the studies; in Section 3.3 we emphasize the interaction approaches present in the studies; in Section 3.1 we highlight the application context and target audience of the studies; in Section 3.4 we present evaluation aspects and data collection methods of the studies; Finally, in Section 3.5 we discuss how the concepts of imagination and embodiment were investigated in each of the selected studies.

3.1 Context and Audience

Regarding the application context of the selected studies, 3 out of the 8 studies refer to exhibition contexts, with two of them being referred to museums (Scott et al., 2010; Erkut et al., 2014), with a target audience of children, and the other one being referred to a closed exhibition (Loke et al., 2012), with a target audience of adults. One study had an urban area as its context (Rossitto et al., 2016) with a target audience of adults. One study took place in people's own homes (Hunter et al., 2014), with a target audience of both children, adolescents, and adults. One study was applied in a community center (Galindo Esparza et al., 2019), with a target audience of people who suffered a stroke. One study did not specify what was its application context or its target audience (Chiu et al., 2013). Lastly, one study did not had a practical application, therefore we considered it as not being applicable with regards to application context or target audience (van Dijk and Rietveld, 2020).

3.2 Used Technologies

As for the use of technologies in the selected studies, in summary, from the 8 studies, 7 (Scott et al., 2010; Loke et al., 2012; Chiu et al., 2013; Hunter et al., 2014; Erkut et al., 2014; Rossitto et al., 2016; Galindo Esparza et al., 2019) proposed some type of technological application. The remaining study (van Dijk and Rietveld, 2020) proposed a more conceptual approach to imagination with no specific technology featured. Different forms of displays (*e.g.*, LCD screen, HD TV, and projector) were employed in 3 studies (Scott et al., 2010; Hunter et al., 2014; Galindo Esparza et al., 2019), tied with Natural User Interface (NUI) technologies (*e.g.,* Microsoft Kinect and Nintendo Wii) which were also present in the same 3 studies. Sensors were present in 2 studies (Loke et al., 2012; Erkut et al., 2014) with the use of heart rate and breathing sensors, and inertial measurement units (accelerometer & gyroscope), respectively. Micro-controllers (*e.g.,* Arduino and XBee) were used in 2 studies (Scott et al., 2010; Loke et al., 2012). Smartphones were used in 2 studies (Chiu et al., 2013; Rossitto et al., 2016), with the latter study using a Global Positioning System (GPS). Traditional computers were used in 2 studies (Hunter et al., 2014; Galindo Esparza et al., 2019). Some kinds of technologies were featured in a single study only, such as: Single-board computers such as the Rapsberry Pi and actuators such as LED's (Erkut et al., 2014); Wearable and embedded technologies (Loke et al., 2012); and, lastly, robots (Scott et al., 2010).

3.3 Interaction Approaches

Regarding to the kind of interaction featured in the applications, tangible interaction (Ishii and Ullmer, 1997), *i.e.*, interaction through the manipulation of physical objects, was the most prominent by being present in 3 studies (Chiu et al., 2013; Scott et al., 2010; Erkut et al., 2014). Embodied interaction (Dourish, 2001), *i.e.*, interaction with technology that involves a person's body in a natural and significant way was present in 1 study (Galindo Esparza et al., 2019). Akin to the concept of an enactive system (Kaipainen et al., 2011), *i.e.*, a dynamic coupling between human body and technology, interaction through physiological data was present in 1 study (Loke et al., 2012). Lastly, concerning more conventional styles of interaction, interaction through movement and geolocation was present in one study (Rossitto et al., 2016); 1 study featured an input/output interaction through gestures and the use of common peripherals such as mouse and keyboard (Hunter et al., 2014).

3.4 Evaluation and Data Collection

Concerning evaluation aspects, 6 out of the 8 selected studies conducted some kind of evaluation (Scott et al., 2010; Hunter et al., 2014; Erkut et al., 2014; Rossitto et al., 2016; Galindo Esparza et al., 2019; Loke et al., 2012). Based on a set of evaluation topics drawn from the content of the selected studies, we classified the evaluation approaches within four categories (it is important to emphasize that these categories are not mutually exclusive, *i.e.*, one study may feature more than a single category in its evaluation):

1. *Experience*: it emphasizes human aspects of the experience with a practical application;

2. *System*: it addresses the proposed technical application and its qualities;
3. *Interaction*: it focuses on the interaction between human being and computational system; and
4. *Workshop*: it targets the conducted activities of the study as part of the use of a practical application.

A focus on aspects of people's experience is present in the evaluations of 4 studies (Hunter et al., 2014; Rossitto et al., 2016; Galindo Esparza et al., 2019; Loke et al., 2012). Regarding specific aspects, social interaction was assessed in two studies (Galindo Esparza et al., 2019; Rossitto et al., 2016); in the first study, researchers evaluated the role of social interaction in shaping the performance of the participants with the proposed system; the second study observed how audience members interacted with each other and with the surrounding environment, including other people who were present where audience members were. People's motivation was assessed in one study (Hunter et al., 2014), in which the authors assessed the participants behavior when interacting with the created application and how it related to their motivations to use it. The concept of embodied imagination is present in 2 studies (Loke et al., 2012; Galindo Esparza et al., 2019), both observing the relationship between bodily experience (in the phenomenological sense (Merleau-Ponty, 1962)) and imagination. Also in the phenomenological sense, one study (Galindo Esparza et al., 2019) investigates how the use of embodiment contributes to the development of fantasy ideas.

An emphasis on the aspects of the interaction between people and a computational system is present in the evaluations of 4 studies (Scott et al., 2010; Hunter et al., 2014; Erkut et al., 2014; Rossitto et al., 2016). In these studies, the researchers observed the participants as they interacted with a technological artifact or application with the objective of identifying interaction patterns (*e.g.,* how people first interacted with the application, how they responded to specific situations, *etc.*). These patterns may be used to assess the usability of the application and use these results to improve it.

An emphasis on aspects and qualities of the system design is present in two studies (Hunter et al., 2014; Erkut et al., 2014). These two studies evaluated the application and any related technological artifact in terms of its design characteristics. Lastly, a focus on the workshop of the study and its respective conducted activities is present in one study (Galindo Esparza et al., 2019). The researchers made a comparative evaluation of the performance of the participants as it was witnessed in the workshop where it was compared to other regular activities of the "life after stroke" group in the community center where the study took place.

Regarding the methods of data collection in the evaluation processes, we identified 4 categories: video recordings, observation, interview and questionnaire. Some studies used more than one data source for evaluation. In the following sections we briefly describe each of these categories and how they were used in the selected studies[4].

3.4.1 Video Recording

Data collection through video recording is present in 4 studies (Scott et al., 2010; Hunter et al., 2014; Erkut et al., 2014; Galindo Esparza et al., 2019). These studies collected data using video recordings to capture, for example, interactions with the artifact and technology (*e.g.,* (Scott et al., 2010; Galindo Esparza et al., 2019)), and behaviors and actions of the participants (*e.g.,* (Hunter et al., 2014; Galindo Esparza et al., 2019)). In one study (Erkut et al., 2014) the participants followed the think-aloud protocol while exploring the prototypes. Another study (Galindo Esparza et al., 2019) used audio recording as a complement to video recording.

3.4.2 Interview

Interviews with participants is used as a data collection method in 4 studies (Loke et al., 2012; Hunter et al., 2014; Rossitto et al., 2016; Galindo Esparza et al., 2019). One study (Loke et al., 2012) conducted a semi-structured interview with participants to capture data about their experience, specifically about the relationship between felt bodily experiences and imagination. The authors used audio recording to complement the interview, so that they could be transcribed later. One study (Hunter et al., 2014) use the interview with participants to assess the application's design and aspects of people's experience. In another study (Rossitto et al., 2016), in turn, the participants were interviewed about their opinion and impressions about the experience with the application and location-based elements. Lastly, one study (Galindo Esparza et al., 2019) conducted a semi-structured interview to explore the participant's experience during the workshop, as well as to discover the post-workshop effects and make a comparative assessment with the usual group activities.

[4]A more in-depth analysis of evaluation in interactive installations is presented in (Mendoza et al., 2022).

3.4.3 Observation

Observation of interaction situations through notes and photos is used as a data collection method in 3 studies (Scott et al., 2010; Hunter et al., 2014; Rossitto et al., 2016). In one study (Rossitto et al., 2016), for instance, the authors observed aspects of people's interactions with each other and the surrounding urban environment they were currently at, as well as interactions with the proposed application and how these aspects reflected on the experience.

3.4.4 Questionnaire

A questionnaire is used as a data collection method in 1 study (Galindo Esparza et al., 2019). The authors created and applied a specific questionnaire to the people at the community center who coordinated the workshop for people who had a stroke. The objective was to collect opinions about the process of the workshop, and to obtain a comparative evaluation of the workshop in relation to other regular activities of the group at the community center.

3.5 Imagination and Embodiment

Regarding imagination and embodiment, by reading and analyzing the selected studies with the frame of our research questions we identified categories to describe how these concepts are approached and how they can be interconnected. For embodiment, we identified 3 categories:

- "*Embodied Interaction*": an approach aligned with the concept introduced by (Dourish, 2001) of interaction with technology that involves a person's body in a natural and significant way;
- "*Action and Perception*": a common sense approach of embodiment, not necessarily following a specific author or theory, as the use of the body in processes of acting upon and perceiving the world; and
- "*Sense-making*": an approach of embodiment that gives emphasis on understanding how we interpret and make sense the world we live in through our actions upon and perceptions of it.

For imagination, we identified 4 categories:

- "Embodied Imagination": an approach to imagination as an enactive and coupled process that is inseparable from our physical bodies and its sensorimotor capacities;
- "Situated Imagination": an approach to imagination as part of a temporally extended active process that involves a broad practical context and anticipates future possibilities of activities;
- "Metaphorical Imagination": like a figure of speech, an imagination metaphor is not a literal representation, but rather itself something original that is inherently connected to something else; and
- "Representational Imagination": an approach of imagination as internal, literal representations constructed through the manipulation of symbols (*e.g.,* language, colors, shapes, *etc.*).

Table 2 presents the categories for embodiment and imagination in which each selected study is more aligned to, according to our understanding. Although these categories are not necessarily mutually exclusive, we chose to select a single category for each study with the rationale of selecting the most prominent one. In the following sections we dive deeper into how each study explores the concepts of embodiment and imagination.

In "Dermaland", (Scott et al., 2010) addressed embodied interaction with tangible technology. In their study, children interact with the installation and move tangible objects to explore and actively participate in the installation. By using metaphors from dermatology and ecology to compose the Dermaland installation, the authors aimed at raising children's awareness of the risks of ultraviolet radiation to human skin. This approach enables children to experience more abstract concepts through interactive play.

Regarding imagination, the metaphor that makes up the installation itself, the use of a magnifying glass during the interaction, represents a metaphor of exploring that piece of land or human skin. This creates the possibility of understanding closely what is being observed. By engaging with these metaphors, children could imagine and create associations based on their prior knowledge.

In "Bodily Experience and Imagination", (Loke et al., 2012) highlighted the perception and performance of one's own bodily processes (*e.g.* breathing and heartbeat). The majority of the interaction with the installation takes place through the use of the participants' physiological data. Data is captured by sensors and amplified through digital soundscapes. According to the authors, the interactions developed in the installation were designed to draw attention to the links between felt bodily experience and imaginative exploration processes, which the boundaries between the self and the world are reinvented through processes of scale and metaphor. With a more common sense approach of embodiment, without emphasizing a specific author or theory, this study falls into the "Action and Perception" category of embodiment.

Table 2: Analysis of Imagination and Embodiment categories in the selected studies.

Study	Embodiment	Imagination
(Scott et al., 2010)	Embodied Interaction	Metaphors
(Loke et al., 2012)	Action and Perception	Embodied Imagination
(Chiu et al., 2013)	Embodied Interaction	Metaphors
(Hunter et al., 2014)	Embodied Interaction	Representation
(Erkut et al., 2014)	Embodied Interaction	Metaphors
(Rossitto et al., 2016)	Sense-making	Situated/Association
(Galindo Esparza et al., 2019)	Embodied Interaction	Embodied Imagination
(van Dijk and Rietveld, 2020)	Embodied Interaction	Situated imagination

In their study, imagination was directly connected to the use of the body in which breathing and pulse are part of the "narrative" built throughout the experience. The authors used the term embodied imagination to refer to the intertwining of human imaginative capacities and the body's felt experience. During participation in the performance at different times, participants were led to imagine themselves as parts of a whale's body leading to scale their sense of self beyond their physical skin.

In "Enabling Interactive Surfaces by Using Mobile Device and Conductive Ink Drawing", (Chiu et al., 2013) investigated how embodiment arises through the tangible and aesthetic interaction with the prototype application developed by the authors. The interaction process featured in their study involves drawing with conductive ink and touch gestures, combined with a smartphone to compose sound feedback. This interaction allows users to create and see their drawings, feel the result of their work with touch and receive auditory feedback, directly exploring at least 3 forms of the user senses. This can be considered as an embodied interaction approach, as the interaction with the technological application involved the user's body in a natural and significant way.

Regarding imagination, the authors argue that aesthetic interaction can stimulate imagination. This occurs by encouraging people to think differently about interactive systems in terms of what these systems do and how they can be used to meet different, creative goals. In their study, imagination is approached through metaphors developed through the emergent drawings, sounds, and touch, as well as interactions that take place during the use of the application, which are associated with previous experiences of the audience with other devices and materials.

In "WaaZam!", (Hunter et al., 2014) feature, among other possibilities, interaction through gestures. Users had the freedom to move from one stage to another and interpret their creations. Even if this kind of movement does not directly imply interaction with the computational system in the sense that it was not used as input, it can still be considered interaction with a broader understanding of system that goes beyond the computer. Concerning the use of the body in a natural and significant way, this study fits into the "Embodied Interaction" category.

As for imagination, it was approached from a representational point of view. Using the perspective from the context of play and games, the authors considered imagination as an essential feature. In these contexts, roles and rules govern the symbolic use of representation. According to the authors, imagination precedes play as the ability to think differently helping children to imagine the perspective of others and connect themselves. Their proposal included the customization and creation of scenes, allowing users to create and modify scenes and support playful activities that incorporate imagination.

In "Design and Evaluation of Interactive Musical Fruit", (Erkut et al., 2014) present an application that had as inspiration the concept of embodied interaction as proposed by (Dourish, 2001). The interaction with the installation involves manipulating fruits placed on a tree to produce sounds and control characteristics of that medium, such as volume. Besides the explicit mention of the category, the use of the body in a natural and significant way indicates that this proposal fits the category of "Embodied Interaction".

As for imagination, the authors used enactive metaphors to enable children understanding of musical expressions and concepts. Enactive metaphors, in this context, are metaphors that bring something new into existence only through our action on a certain object or idea. In this case, through the act of manipulating musical fruits, children produce and manipulate sound characteristics, effectively bringing something new into existence.

In "Interweaving place and story in a location-based audio drama", (Rossitto et al., 2016) present a view of embodiment as originating from the creation of meaning that comes with the embodied experience. In particular, this occurs with their application when users walk around the city and trigger the proposed narrative. The story presented is interpreted by the users while intertwined with their personal and situated experience of the places in which they are located. This personal inclination of users to place and

engagement through technology can spark imagination and meaning-making.

This formation of meaning is directly linked with imagination. The authors highlight the relevance of connecting location technology to physical locations to illustrate how imagination and open interpretation emerge as users seek to make sense of these relationships. On several occasions, users' imagination was triggered by elements that were presented in places regardless of the audio from the application, and were intertwined with the narration. According to the authors, the users' open interpretation promotes their role as active meaning creators. With subtle suggestions, this coupling was enough to provide personal and sometimes unexpected interpretations.

In "Embodied Imagination", (Galindo Esparza et al., 2019) presented an approach to embodied interaction through body movements, such as arms, legs, *etc*. The authors studied the concept that through the movements captured by a Kinect, and the visual feedback offered by an application, users could place themselves in imagined places and situations.

Interaction through movements allowed users to incorporate their fantasies and explore their imaginations while telling their narratives. By observing the interaction of workshop participants with the application, the authors indicated that the majority of the participants moved throughout the space and used their entire body to incorporate fantasies. Qualitative assessments suggested that this process successfully stimulated embodied imagination.

In "Situated imagination", (van Dijk and Rietveld, 2020) feature no technological application. However, embodiment is an important concept in the study and is deeply tied with imagination. Their work addresses a situated view of imagination, *i.e.*, imagination is situated in a context and is temporally extended. According to the authors, imagination is not considered as an individual's pre-determined state, but it is part of a process that coordinates a history of activities, a broad present practical context, and an anticipated path of future activities. In this approach, the organism's bodily sensitivities (*e.g.* a visual system), while not sufficient, are necessary for imagination. The identification of multiple affordances developed simultaneously can be experienced as imaginative. The indeterminate arrangement of this process allows activities to expand, enabling new action possibilities. In this process, the active involvement of the body contributes to the development of these possibilities.

4 DISCUSSION

In this section we discuss our systematic literature review results within the frame of our research questions. In the following sections we discuss the main topic of each of the three research questions presented in Section 2.1. Lastly, in the format of highlights for a research agenda, we provide insights regarding open research challenges we detected.

4.1 Installations and Imagination

Regarding the Research Question #1, "*How do interactive installations based on ubiquitous and/or enactive technologies explore the concept of imagination?*", we found that 5 of the 8 selected studies used ubiquitous technologies (*e.g.*, sensors with 3 occurrences, microcontrollers with 3 occurrences, Microsoft Kinect with 2 occurrences, and the Nintendo Wii with 1 occurrence). In these studies, imagination was approached through metaphors (Scott et al., 2010; Erkut et al., 2014), representation (Hunter et al., 2014), or as embodied imagination (Loke et al., 2012; Galindo Esparza et al., 2019). We consider that these technologies, especially when wireless and embedded into the environment, can contribute to creating scenarios where technology is not at the forefront. They can help "hide" system complexity, enabling the creation more immersive environments where users can focus on the experience and in the situated context. instead of on the technology itself. Among these technologies, we highlight the innate play aspect found in the Nintendo Wii and the Microsoft Kinect. They provide possibilities for users play with and act on a given idea, potentially creating enactive metaphors.

Looking further into the studies of (Scott et al., 2010) and (Erkut et al., 2014), which approached imagination through metaphors, the associations made between objects and concepts enabled users to imagine narratives (in the first case to learn about ecology and dermatology, or to create music in the second case). The study of (Hunter et al., 2014), in turn, addressed imagination through representation. These authors considered that the imaginative process takes place through the representation of ideas. In their proposal, users imagine and create narratives representing elements through images in the customization tool offered by the application. Lastly, in the studies of (Loke et al., 2012) and (Galindo Esparza et al., 2019) imagination was approached as being embodied, *i.e.*, it is developed with the involvement of the body. In (Loke et al., 2012), although the body and its sensorimotor capabilities are a central aspect of the study, the imaginative process is seen

as image formation, specifically the use of images to transform the perception and experience of oneself and the world. This refers to an approach to imagination that can be considered as representational, because the "content" imagined is "pre-existing" and represented. In this sense, it diverges from the enactivist approach as proposed by (Varela et al., 1993).

In the remaining 3 studies that did not use ubiquitous technologies (Chiu et al., 2013; Rossitto et al., 2016; van Dijk and Rietveld, 2020), imagination was approached through metaphors in the first one and as situated in the last two. For (Chiu et al., 2013), imagination happens through associations made through drawings, sounds and previous experiences from other contexts. For (Rossitto et al., 2016) and (van Dijk and Rietveld, 2020), imagination is situated, *i.e*, it occurs according to the context and environment in which a person is situated. The imagination itself develops from the possibilities offered by this context.

4.2 Evaluating Imagination

With respect to the Research Question #2, "*How is the use of imagination evaluated in ubiquitous and/or enactive interactive installations?*", our investigation reveled that 6 out of the 8 selected studies applied some evaluation procedure. As presented in Section 3.4, evaluation approaches examined either the experience of the participant, qualities of the system, aspects of the interaction, the workshop itself, or some combination of these categories. Of these subjects of evaluation, while some of them come from the legacy of evaluating conventional computer systems (*e.g.*, usability, user experience, engagement, attention, performance, *etc.*), there are also some emerging new interests, such as social interactions and the use of embodiment to develop fantasy/imagination ideas.

Regarding data collection methods, we observed a preference in the selected studies towards video recordings and interviews. These methods were used to collect data about interaction experience, including artifacts and their design. Video recordings were particularly important in allowing researchers to assess social aspects, while interviews were used mostly to assess users' involvement with the technology. One study in particular (Erkut et al., 2014) used the think-aloud protocol to supplement data collection from video recordings. Observations (annotations and photographs) were primarily used to gather information about people's experience and interactions, and to assess artifacts and their design. Questionnaires were applied to assess the experience with a workshop. In general, interviews and questionnaires were mainly used to collect data about people's experience whereas video recordings and observations were mainly used to capture people's interactions with the developed applications and with others.

From the 6 studies that evaluated some aspect of the proposed application, 2 specifically investigated imagination in their evaluations (Loke et al., 2012; Galindo Esparza et al., 2019). Both studies assessed the relationship between bodily experience and imagination. The instruments were interviews and video recording. When considering the relevance of action to imagination, we observed that no specific method was employed to assess environments in relation to their possibilities for actions.

4.3 Imagination and Embodiment

As for the Research Question #3, "*How does embodiment help to explore human imagination in ubiquitous and/or enactive interactive installations?*", we highlight that embodiment contributes to active imagination (see Section 3.5). In two of the selected studies (Loke et al., 2012; Galindo Esparza et al., 2019), the term "embodied imagination" appears to refer to the link between the imaginative capacities of human beings and the felt body experience. The body's involvement with the affordances provided by the environment, context, objects, and people allows the imaginative process to be situated and active.

In the selected studies, body movements allow the creation of fantasies and narratives, as well as the manipulation of tangible objects. This allows users to create embodied metaphors and integrate them into their stories. In terms of conceptual foundation, however, we observe that few studies addressed imagination from an enactivist point of view with proper grounding on theories and concepts, going beyond the mere inclusion of the physical body in the interaction. This leads to most of the selected studies to present what can be considered a more generic, common sense understanding of embodiment, embodied interaction, and imagination. This limitation can substantially distance studies from the understanding that the imaginative process is facilitated and nourished by the coupled connection between the individual's body, situated context, and the employed technology. In this context, the possibilities offered by affordances, a concept deeply tied with enaction, are the sources that spark the imagination.

As examples of studies that do give more theoretical and practical grounding to their use of "embodiment", the works of (Loke et al., 2012), (Galindo Esparza et al., 2019), and (van Dijk and Rietveld, 2020) view "embodied interaction" as going beyond the living organism and expanding to the social and cultural

context. This includes experiences and possibilities, extending, albeit timidly, to the imagination.

4.4 Highlights for a Research Agenda

Results of our systematic literature review indicate that imagination has been approached in contexts of interactive installations. However, we identified missing aspects and open challenges that create opportunities for new research. In the following, we summarize a research agenda with aspects we understand as key opportunities for further studies.

4.4.1 Imagination as a Concept

Although the selected studies have addressed the concept of imagination, the research community could benefit from going further into the types of experiences provided by exploring imagination. It is noticeable that there is a lack of grounding and conceptualization regarding imagination. This can be, in part, explained by how it is a complex task to contemplate the imaginative process while designing interactive technologies. This challenge opens opportunities for creating design recommendations aimed at fostering imagination in interactive systems. Recommendations or guidelines aimed at supporting imaginative processes and related aspects can be useful for designers in the conception of novel interactive installations. As an example, these recommendations or guidelines could explore aspects such as creative freedom and the situated nature of affordances with relation to context, objects, technologies and people.

4.4.2 The Coupling of Imagination and Embodiment

The theory of enaction and the concept of embodiment open new opportunities to approach imagination in the design of computational systems. Although we found and selected studies that explored both embodiment and imagination, the number of selected studies (8), especially considering our search interval of about 10 years, show that the combination of imagination and embodiment is still timidly explored in the literature. Furthermore, few studies consider that embodied action can contribute to active imagination. Imagination was almost always approached as something passive, which occurs in the face of things we already know and are only represented to us later. We, however, see imagination as active and embodied.

Embodiment allows imagination to be active, open, and situated. The human being is continuously situated in a wide context of involvement with opportunities for action offered by other people, materials, tools, texts, *etc*. For instance, through the capture of physiological data, added to physical experiences with objects placed on our bodies, and sound and visual feedback, we can imagine ourselves as going beyond the limits of our very skin. In summary, the design of interactive systems considering the coupling between embodiment and imagination opens up as a promising opportunity for research.

4.4.3 Reachness of Methods

Out of the 6 selected studies that featured some form of evaluation, 5 used more than one data collection method (some used up to three methods (Hunter et al., 2014; Galindo Esparza et al., 2019)). This suggests that a significant number of researchers consider that a single data collection method is not sufficient to address assessment in ubiquitous and pervasive technology scenarios. We understand that multiple data collection methods and instruments may be needed to properly consider imagination aspects in an evaluation procedure. In fact, these scenarios provide a great diversity of aspects to be considered in an assessment process, such as people's freedom to explore their ideas and affordances provided by the environment, context, or artifacts. Thus, it is unlikely that a single known method provides sufficient answers.

Although different data collection methods can be useful for researchers to explore various aspects of ubiquitous systems in a complementary way, there is still a need for more specific methods. For instance, there is currently no evaluation method or instrument to specifically investigate how imagination can be explored when interacting with applications. Two of the selected studies were interested in evaluating how body and action influence the imaginative process. However, due to the lack of more specific methods, they were still limited in identifying how and if imagination was developed, and to which extent did the environment offer possibilities to nourish imagination.

5 CONCLUSION

Pervasive and ubiquitous technologies permeate our lives and have created new forms of interaction, which requires new approaches to system design. Interactive installations and their exhibition spaces stand as an instance of this type of system. They are often at the forefront of interaction design for their constant experimental use of technology and envision of new, unconventional interaction approaches. In this article, we presented a systematic literature review to unfold and better understand existing studies that ad-

dress imagination and embodiment in interactive installations. Our results indicate that, while there are important, pioneer works in the literature, the design of enactive interactive installations still requires more research on how to explore the concept of imagination. We found that existing studies do not present specific evaluation protocols for addressing and evaluating this type of interactive installation, and existing methods, while useful, are still not enough.

Future work involves addressing the opened research agenda. More specifically, we consider the design, implementation, and evaluation of guidelines that follow this research agenda. These guidelines should be able to support designers in the creation of interactive installations suited for augmenting users' imagination and embodiment, contributing with further advances in research on the subject.

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