

Revisiting Interactive Art from an Interaction Design Perspective: Opening a Research Agenda

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ABSTRACT

The articulation of art and science has been an important source of innovation and groundbreaking contributions in many domains throughout history. In this paper, we revisit the concept of interactive art, from an interaction design perspective, aiming at identifying the interaction approaches that emerge in interactive art examples found in the literature and also in other non-academic sources, such as online communities and digital games. Moreover, we investigate the use of frameworks and methodologies to support the design of interactive art. Results of this study illustrate the ways interaction approaches found in interactive art examples can inspire novel forms of interaction, which can also be useful in the design of interactive systems without artistic intent. Furthermore, frameworks and methodologies to support the design and evaluation of interactive art provide different ways to approach the design of interactive systems, giving focus to experiential aspects that otherwise could be overlooked. Lastly, we outline a research agenda to encourage research on interactive art from an interaction design perspective.

CCS CONCEPTS

• **Human-centered computing** → **HCI design and evaluation methods; Interaction paradigms; Interaction techniques; Interaction devices;**

KEYWORDS

Interactive Art, Interaction Design, Literature Survey, Interactive Art Examples, Interactive Art Evaluation

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1 INTRODUCTION

The articulation of art and science has been an important source of innovation and contributions in many fields throughout history. In the Renaissance, for example, the search for knowledge often led to a blurred line between art and science. This interdisciplinarity is often illustrated by the work of Leonardo da Vinci. According to Wilson [75], besides Leonardo's intellectual accomplishments, engineering inventions, and artistic creations, he was also successful in incorporating scientific approaches and theory into his artistic process. The period between the decades of 1870 and 1920 also serves as an example of a much subtler connection. Science had revolutionary breakthroughs that still shape contemporary research. Art, on the other hand, broke conventions about perspective and representation, the role of the self and the unconscious, the nature of artistic materials and contexts, and the relationship of art to social and technological forces, starting movements that still influence contemporary artists. At the same time that the Newtonian worldview was challenged by relativity and quantum mechanics, modern art challenged perspective and classical rules of composition, and cubism questioned the solidity of objects and explored relativistic concepts of time.

Art and science can mutually benefit from a close relationship. According to Wilson [74], artistic traditions such as iconoclasm (constantly challenging or rejecting the *status quo*) and a greater appreciation of subjectivity may allow discoveries that the traditional scientific process would otherwise probably ignore. On the other hand, artists may be able to employ their critical thought and become an active part of the creation of new technologies.

Turning our focus to the field of Human-Computer Interaction (HCI), it is plausible to consider that HCI research that incorporates aspects of art, through the concept of interactive art, may lead to novel contributions. According to Edmonds [34], some artists give great importance to what the audience feels, and consequently, experience plays an important role in art in general. Moreover, in interactive art experience, this is not only important but a central aspect. The interactive experiences are also extending and challenging what the HCI community knows as "User Experience (UX)" design. Benford *et al.*'s "Uncomfortable UX" concept [7], for instance, employs uncomfortable interaction as a strategy to deliver entertaining, enlightening and socially bonding cultural experiences. Furthermore, Weiley and Edmonds [73] argue that HCI researchers can incorporate art approaches to: (1) make some types of decisions more explicit by documenting not only results but also the ideation process; (2) support stronger hypothesis generation by fostering divergent thinking and informed intuition; and (3) enrich evaluation methods by adopting a more reflective practice.

Therefore, the articulation between art and science in HCI should be further encouraged, and this may be accomplished through the study and practice of interactive art. In this paper, we revisit the concept of interactive art from an interaction design perspective by exploring the literature guided by the following research questions:

Q1. What kind of interaction approaches emerge in interactive art examples in the literature and other non-academic sources?

Q2. What kind of frameworks and methodologies are used to support the design and evaluation of interactive art?

This paper is structured as follows: we begin Section 2 by presenting a brief background on the connection between interactive art and HCI. In Section 3 we present an initial categorization of interaction approaches from interactive art examples found in the literature and other non-academic sources. Then, in Section 4 we explore different frameworks and methodologies found in the literature to support the design and evaluation of interactive art. Afterward, in Section 5 we discuss our main findings and contributions, as well as their implications for design, leading to the outline of a research agenda. Lastly, in Section 6 we summarize our main conclusions and present directions for future work.

2 BACKGROUND

Some knowledge and methods related to art have been used in HCI for quite some time. Gestalt and other visual principles, for instance, have been applied with relative success in visual design. Furthermore, the methodology described by Frayling as Research through Art and Design [43] has been gaining attention within the HCI community in recent years [5, 46, 76]. Among many possible approaches to articulate art and science in HCI, in this paper, we focus on something that inhabits both the worlds of art and HCI for some decades, but somehow always manages to reinvent itself and retains a feeling of novelty and innovation: the theory and practice of interactive art.

Regarding the concept of “interactive art”, it is argued by Muller *et al.* [61] that the act of “experimenting” any kind of art is always an active and fundamentally interactive process. In this case, the interaction occurs in the process of perception and creation of meaning in the mind of the audience. The authors, however, discuss how the advent of art with computer-based interactivity started what is now broadly recognized as interactive art. In interactive art as it is now known, interactivity transcends the psychological by ceasing to occur only in the mind of the audience as interpretation: now, audience and artwork perform a two-way sensory-motor material exchange, forming an interactive dialogue that has the potential to be unique for each audience. Therefore, considering how our investigation is focused on HCI and interaction design, in this paper we consider interactive art to be any form of art enhanced with computer-based interactivity. Other forms of interactivity in art that do not involve computers, such as the exploratory works of Brazilian artists such as Hélio Oiticica and Lygia Clark, although valuable in their pioneering and other aesthetic qualities, are beyond the scope of this paper.

Interactive art and HCI share common origins, as it is pointed out by England [36]. Before the emergence of HCI as we currently know it, in the decades of 1960 and 1970 several artists were getting involved with modern technology and creating the first digital interactive experiences. Krueger’s GLOWFLOW and VIDEOPLACE projects [57], for instance, date from 1969 and 1974 respectively. Almost at the same time, Engelbart devised his “Augmenting Human Intellect: A Conceptual Framework” tech report [35], which was the foundation for many future innovations such as the first interactive windows and mouse systems. This common origin between interactive art and HCI, however, was left aside in the decade of 1980, when HCI was formalized as a field with computer science and cognitive psychology as predominant voices. Initially, there was no substantial space for more subjective interaction aspects. It was only a few decades later that aspects such as culture and non-work-related activities started to gain more attention, in a period described by Bødker [9] as “third-wave HCI”. Much like some ideas from third-wave HCI, Edmonds [34] discusses the way interactive art is not exactly concerned with task analysis, error prevention or task completion times. Goals may not be well defined, and focus tends to be on pleasure, play, experience, and engagement.

According to England [36], since the first years of the 2000’s, a community effort was made to bring HCI and art closer together. This is illustrated by panels & Special Interest Groups (SIGs) (*e.g.*, [38, 40, 67]) and workshops & art exhibitions (*e.g.*, [1, 37, 39]), mainly at the CHI conference, but there are also contributions in smaller, but not less important conferences, such as Creativity & Cognition [15]. Without exhausting the subject, there have been discussions regarding hybrid evaluation methods that can potentially contribute both to new media arts and HCI practitioners [1]; cataloging the digital arts and reported curatorship experiences [37, 39, 40]; possible articulations of lines of research in digital arts and HCI through intersections and cross-fertilization [38, 42, 67]; the relationships between the interactive arts, audience engagement and experience design [32]; how can HCI research be aligned with socially engaged arts practices that encourage debate around societal challenges [20]; how art and HCI discourses can both inform and be informed by innovation policies and initiatives [41]; and how art and HCI can investigate together the shifting role of the former “user”, who can now become, for instance, an author, collaborator or performer [59].

With the growing number of contributions at the intersection between art and HCI, it is our understanding that interaction designers could benefit from the unconventional thinking and creative efforts that arise from the creation of interactive art in its many forms. This can be achieved by studying interaction approaches found in interactive art examples, both in scientific literature and other sources, as well as design and evaluation approaches employed in the creation of interactive art artifacts, as we will present in the two following sections.

3 INTERACTION APPROACHES

There are several samples of interactive art in the literature and other sources, such as online communities and digital games. We must emphasize that it is not our intention to define what is and what is not interactive art (some examples in this section, in fact,

were not labeled as such by their creators). We encourage readers to explore the concept of interactive art to construct their own understanding of what is (and what is not) interactive art. In this section, we aim to address our first research question Q1 (“What kind of interaction approaches emerge in interactive art examples in the literature and other non-academic sources?”) by illustrating some examples from an interaction approach perspective. By analyzing examples of interactive art from the perspective of HCI with an emphasis on how people interact with the artworks, we derived four high-level categories of interaction approaches. For each category, we selected and described two meaningful examples of interactive digital artifacts constructed with either prior artistic intent from creators, or posterior audience perception as art. The categories are: (1) Virtual; (2) Embodied; (3) Tangible; and (4) Social.

3.1 Virtual Interaction

In the virtual interaction approach, the artwork is mainly virtual (*i.e.*, have a digital representation), and in many cases is experienced through a screen or virtual reality headset with more traditional input methods (mouse, keyboard, touchscreen or game controller.) Usually, these artifacts are designed with a significant degree of aesthetic interest when compared to everyday counterparts. Examples of interactive art with a focus on virtual interaction are:

- (1) *Live Writing: Gloomy Streets* [58], an application in which the experience of writing a poem is enriched with a real-time audio-visual performance on top of what was written. As a person writes in a blank screen with a typeface and sound effects, which resemble those of a typewriter, the text may start to blur and ripple while an enigmatic sound effect plays in the background. The writer’s own emotions emerge through keystrokes and letters that seem to be alive.
- (2) *Journey* [71], illustrated in Figure 1a, a game in which the player controls a character roaming in a vast desert towards a distant mountain. Although it is an online multiplayer game, the player has limited interaction with other players, relying only on communication through character movement and a musical chime. It was not the gameplay that made it very well received by both critic and players alike, but the strong emotional and aesthetic experience, as can be seen in the aggregated reviews available at Metacritic¹.

Other examples include, but are not limited to: *This Is Not Private* [25], *idMirror* [50] and *Fukushima Audio Census* [55].

3.2 Embodied interaction

In the embodied interaction approach, the artwork reaches out to the physical world to receive embodied methods of input that go beyond traditional everyday interaction. Usually, it involves sensors capable of identifying psycho-physiological indicators, and the person’s own body is used for conscious, or even unconscious, interaction with the artwork, as in the concept of an Enactive System proposed by Kaipainen *et al.* [52], drawing upon the enactive approach [72]. Examples of interactive art with a focus on embodied interaction are:

- (3) *iMorphia* [12], illustrated in Figure 1b, an art installation in which a person has its body tracked by sensors so that a computer connected to a projector can project a virtual character over the person’s body. The body tracking sensors allow the projected character to follow the person’s movements in real time. It can be used, for instance, to project famous fictional characters such as *anime* or cartoon protagonists, allowing the person being tracked to physically impersonate the character, challenging basic conventions of screen-based interaction.
- (4) *CAVE* [27], an immersive art installation in which the audience can experience an interactive ritual related to Afro-Brazilian popular religions. Sensors are used to detect physiological indicators and walking patterns from the audience to, accordingly, control projections on the walls and other interactive resources, such as ambient sound. The goal is to “[...] enhance the sensorial experiences and amplify kinaesthesia by adding the sensations that are formed in response to the physical world, which aesthetically constitutes the principle of synaesthesia”.

Other examples include, but are not limited to: *Distractions* [13], *Avian Attractor* [28] and *BrightHearts* [54].

3.3 Tangible interaction

Drawing from the concept of “Tangible Bits” by Ishii and Ullmer [48], in the tangible interaction approach, the artwork goes beyond the virtual and is somehow embedded in real-world objects. It usually involves sensors capable of tracking these objects and sensors in the objects themselves to capture interaction data, and may also involve the concept of Internet of Things (IoT). Examples of interactive art with a focus on tangible interaction are:

- (5) *Crafted Logic* [65], an interactive installation focused on handcrafting simple electronic components from scratch. It consists of handcrafted hardware created with textile-crafting techniques, such as crochet. The hardware is connected forming basic logic gates controlled through electromagnetism and can perform designed logical operations. According to the authors, this installation “[...] challenges the aesthetics, interactions, and technology creation scenarios we take for granted in the field today”.
- (6) *Breaking AndyWall* [53], an interactive installation where participants are invited to “destroy” pieces of art that are socially considered what the author calls “great art”, such as Andy Warhol’s Marilyn Diptych. The artwork is projected onto a canvas that can be hit by the audience with a provided wooden hammer. Sound sensors capture the impact, and with each hit, the projected artwork is gradually broken down into shattered pixels. According to the author, the objective is to provide an experimental space to discuss the dynamic roles of users in art and Design.

Other examples include, but are not limited to: *Endless Ripples* [47], *eBee* [64] and *Dichroic Wade* [66].

3.4 Social interaction

In the social interaction approach, the artwork may not necessarily excel in its degree of aesthetic interest and neither provide any

¹<http://metacritic.com/game/playstation-3/journey>



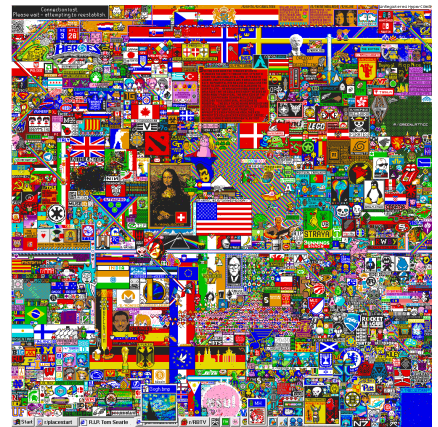
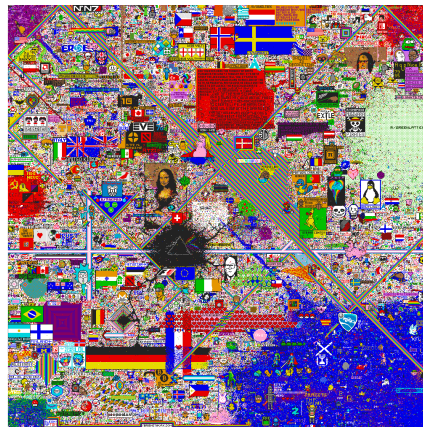
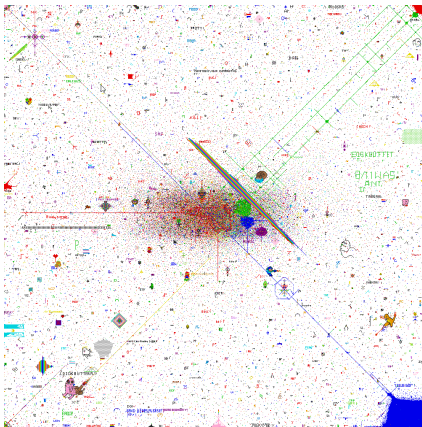
(a) Journey [71] (PlayStation Europe^a, CC BY-NC 2.0).

^a<https://www.flickr.com/photos/playstationblogeurope/4733137250>



(b) iMorphia [12] (Art.CHI 2016 Archive^b).

^b<http://art-chi.org/imorphia>



(c) Snapshots of Reddit's r/place canvas from beginning to end. Reconstructed from Albini's Archive^c.

^c<https://github.com/pietroalbini/reddit-place-2017>

Figure 1: Interactive Art Examples.

novel form of interaction; on the other hand, it may somehow encourage people to interact with each other in unconventional ways through the artwork. Sometimes, this kind of interactive art may even unexpectedly encourage people to collaborate with each other and achieve complex levels of self-organization. Examples of interactive art with a focus on social interaction are:

- (7) *Twitch Plays Pokémon*, a social experiment that is still active by the time we write this paper². Its most memorable moment was the very beginning of February 2014, when thousands of players could simultaneously issue commands to control the character of a live stream play-through of the classic game Pokémon Red [45]. Oscillating between democracy and anarchy, ultimately the players could collaborate with each other to the extent that they surprisingly were able

²<https://twitch.tv/twitchplayspokemon>

to finish the game in precisely 16 days, 9 hours, 55 minutes and 4 seconds.

- (8) *Reddit's /r/place*, a social experiment conducted in April 2017. Users of Reddit, also known as Redditors, were given a shared empty canvas with 1000 × 1000 pixels, and each Redditor could place or paint only one pixel on the canvas every 5 to 20 minutes. The experiment, illustrated in Figure 1c, lasted only three days, but it was enough to show a fierce competition between different groups of people for the limited pixels, as well as complex levels of self-organization and collaboration between people with shared interests. As an attempt to catalog everything that was created during the three days of the Reddit's /r/place event, the r/place Atlas³ has 1493 entries.

³<https://draemm.li/various/place-atlas/>

Other examples include, but are not limited to: *Tango Apart: Moving Together* [33], *Whorl* [60] and *Sprung!* [21].

Concerning HCI, interactive art can take many forms and be analyzed from many angles. Our proposed interactive art categories and examples illustrate some of these angles. Besides the humanistic value that may or may not be intended, from an interaction design perspective, these examples provide a basis to understand further research on important topics of HCI. The provided examples encompass, for instance, properties that led to high levels of immersion and engagement; novel forms of interaction with computer systems based on alternative technologies and sensors; and social behaviors of collaboration (or competition) and self-organization through computer systems.

It is important to emphasize that these different interaction approaches are not mutually exclusive, and they are not intended as a strict nor comprehensive categorization of interactive art. The Twitch Plays Pokémon and Reddit’s /r/place examples, for instance, could also be considered examples of virtual interaction, while embodied and tangible interaction can easily become intertwined.

4 DESIGN AND EVALUATION APPROACHES

Bannon and Ehn [3] and Kostakos [56] argue that HCI communities often focus on results, products, and services, while the design processes and practices often lack thorough presentation and discussion. However, besides analyzing interactive art examples, we may also benefit from studying how these artifacts are created. In this section, we aim to address our second research question Q2. (“What kind of frameworks and methodologies are used to support the design and evaluation of interactive art?”) by briefly discussing some methods and frameworks from the literature that we consider relevant to our study, without exhausting the subject. We will give particular emphasis on evaluation, as it is one of the central aspects of HCI practice and research, and it often informs design in a formative manner.

Evaluation can be approached from many angles regarding objectives and methodologies. Leaning on a summary of the three HCI waves under the lens of Philosophy of Science and research paradigms by Duarte and Baranauskas [29]:

- First-wave HCI approaches to evaluation appear to be more concerned with finding ergonomic universals and quantifying interaction metrics, relying on experimental methods;
- Second-wave HCI approaches focus appear to be on evaluating how the human mind can process information displayed by a computer and communicate back through a user interface, making use of both experimental methods and more naturalistic inquiries to derive “universal laws”; and
- Third-wave HCI approaches appear to be more concerned with evaluating aspects of UX that go beyond work-related and “purposeful” interaction, relying on both experimental methods and more naturalistic inquiries to understand different facets of reality.

In art, on the other hand, Candy [14] argues that evaluation is usually an unfamiliar practice, and sometimes even a rejected notion among artists – even though some form of evaluation may

implicitly occur in the art-related activities of critique and curatorship. According to the author, however, there are pioneer practitioners and researchers that are exploring forms of evaluation that impact on how art is made and exhibited. Drawing on Dewey’s notion that “[...] art is complete only as it works in the experience of others than the one who created it.” [26], interactive art creators can opt to give away control of their creation to allow other people to “complete” their work by experimenting with it. This experience focused approach supported by evaluation methods may allow not only the discovery of new knowledge on engagement and UX but also the creation of new artworks altogether.

Considering that HCI researchers and practitioners have had decades to propose, design, study and put into practice a wide range of evaluation methods, this accumulated theoretical and practical experience may prove useful for pioneer artists interested in exploring forms of evaluation for their artworks. In turn, the use of HCI evaluation methods in different artistic contexts, and with unorthodox objectives, has the potential of shedding light on aspects not yet considered, possibly further improving such evaluation methods and contributing to HCI research. Evaluation, therefore, can be viewed as a practical common ground between art and science in HCI. In the following subsections, we examine two frameworks designed to support the design and evaluation of interactive art. These frameworks may provide a better understanding of possible directions towards a common ground, as well as insights for the evaluation of interactive systems without artistic intent. Afterward, we briefly discuss the use of participatory approaches to the design of interactive art.

4.1 Candy’s Framework

Aiming to support higher level problem clarification regarding interactive art, Candy [14] proposes a generalized design and evaluation framework composed of four categories: (1) Participants; (2) Experience; (3) Outcomes; and (4) Environment. Candy’s evaluation framework is designed to clarify the elements of a design and/or evaluative process and the features to be designed and/or evaluated, along with applicable criteria, qualities or values. It may be summarized as follows:

- **Participants:** May include artists, technologists, audience, curators, organizers or even funding bodies; Which may lead to the evaluation of features such as imagination, expertise, skill, experience, intention, reputation, success or failure; With criteria considering levels or degree of motivation, skill, education, expertise, engagement, curiosity, commitment or resources.
- **Experience:** May encompass audience engagement, art practice, curatorship or system development; Which may lead to the evaluation of features such as response, attitudes, risk-taking, interaction, innovation, design quality or performance; With criteria considering levels or degree of the experience being positive, negative, opportunistic, adventurous, curious, cautious, experienced or transcendent.
- **Outcomes:** May be artworks, installations, exhibitions, performances or compositions; Which may lead to the evaluation of features such as novelty, originality, impact, adaptability, aesthetics, effectiveness or appropriateness; With criteria

considering levels or degree of qualities such as leading edge, engaging, purposeful, enhancing, exciting or disturbing.

- **Environment:** May be a studio, laboratory, museum, gallery or public space; Which may lead to the evaluation of features such as physical spaces, facilities, costs, time, resources, effort, constraints or support; With criteria considering levels or degree of qualities such as design quality, convincing, adaptable, effective, innovative, sufficient, sustained, damaging or copious.

4.2 Costello's Pleasure Framework

Aiming at identifying what constitutes pleasure in what the authors refer to as “playful interaction”, Costello’s pleasure framework [21, 22] is composed of thirteen categories of pleasure that can be experienced when interacting with interactive art. According to the authors, the framework can be used both to support the design, as well as to evaluate playful interactive experiences. The framework’s categories, with some considerations of our own in parenthesis, are:

- **Creation** is the pleasure from being able to create and express yourself creatively, obtained from the aesthetic qualities of the creation or simply from being in control (*for an artwork to excel in this category it seems plausible that it must not only be interactive, but also participatory, elevating the audience to the status of co-authorship*).
- **Exploration** is the pleasure from exploring something or a situation that is unfamiliar. It is often linked with Discovery, but sometimes it may also be self-contained.
- **Discovery** is the pleasure obtained from making a discovery, like discovering relationships between performed actions and respective responses from an artwork or even finding a solution to a problem (*the amount of pleasure for finding a solution to a problem seems correlated with Difficulty*).
- **Difficulty** is the pleasure from developing or exercising a physical or intellectual skill to do or achieve something, as an activity may often be more fun if it is not too easy (*there may, however, be a fine line between achieving this pleasure and being frustrated with a too high difficulty*).
- **Competition** is the pleasure from achieving a system or self-defined goal. This goal may or may not involve working with or against another physical or virtual entity (*when Competition is between people and not a virtual entity, it may be even a harder task to adjust Difficulty without frustrating one or both competitors, as Difficulty cannot be explicitly controlled anymore*).
- **Danger** is the pleasure from feeling scared, in danger or as taking a risk. This feeling may vary between simply feeling a mild sense of unease, to a strong feeling of fear, and may occur indirectly through empathy for another entity.
- **Captivation** is the pleasure from feeling mesmerized, like being in some way controlled by another entity. It may happen, for instance, through an immersive experience that leaves the audience unconscious of its surroundings.
- **Sensation** is the pleasure from feeling a sensory physical action, e.g., touch, hearing etc. (*besides being a category on its own, the multisensory nature of Sensation leads us to think of*

it as also an underlying aspect of the other categories, as our senses are directly related to all of them).

- **Sympathy** is the pleasure from sharing physical or emotional feelings (*as we understand, Sympathy is inherently reciprocal, as sharing feelings in the terms of simply exposing them may not be enough to achieve pleasure from this category. Reciprocity seems to be essential*).
- **Simulation** is the pleasure from perceiving a copy or representation of something from real life (*in our understanding, the Simulation category may not be limited to representations from the real, physical world; a physical or virtual representation of something virtual may also invoke the described pleasure*).
- **Fantasy** is the pleasure from perceiving a fantastical creation of the human imagination, like the representation of peculiar fictional worlds and creatures.
- **Camaraderie** is the pleasure from developing a sense of friendship, fellowship or intimacy with someone (*this category seems highly likely to be linked with Competition and Sympathy, and it seems fundamental to achieve behaviors of collaboration and self-organization*).
- **Subversion** is the pleasure from breaking rules, subverting the meaning of something or watch someone else do it (*in doing something not allowed or predicted by the system, this category may be linked with Exploration, Discovery, and Creation, as well as Danger in some circumstances*).

According to the authors, it is not feasible for an interactive artwork to excel in all categories at the same time, and this should not be the goal altogether. The authors are more concerned with surfacing and understanding possible aspects of playful interaction that may or may not lead to some form of pleasure for people interacting with an artifact, as well as identifying which categories stand out in an artwork.

4.3 Participatory Approaches

The use of participatory approaches in the design of interactive art or interactive installations has been reported in scientific literature for over a decade. Frecon *et al.* [44], for instance, reported on how a museum installation about visualizing sound perception in submarines was redesigned with participatory activities with stakeholders to collect design suggestions. There is a significant amount of publications that present interactive installations designed with some kind of participatory design approach (e.g., [10, 24, 62, 68]). However, these studies tend to have their contributions oriented towards showing the created product qualities, while details of the design process are often not presented or not thoroughly discussed.

For studies that do give a greater emphasis to the design process, many highlight the use of participatory approaches in early design phases to generate ideas and concepts. Some studies present the benefits of conducting fieldwork at the intended environment for an interactive artifact or installation [17, 18]. Some studies present a variety of early phase approaches to design, such as rapid an ethnographic study in a museum setting [63], integrating stakeholders into the design team to open-endedly generate design ideas, or developing early prototypes to gather feedback from users to lead

the design from there [16, 51], and showing the feasibility of including children in the process to generate ideas for a virtual reality exhibit [69]. In a more holistic approach, Ciolfi *et al.* [19] describe a co-design process that iterates phases of generation of new concepts (divergent activities) with the selection of concepts to pursue (convergent activities). The authors describe the use of practical, embodied activities such as sketching in hardware, in-situ scenario building, bodystorming and combining technology and content.

Perhaps the most controversial aspect of it, participatory approaches may challenge traditional understandings of the concept of authorship, leading to the concept of co-authorship of interactive art. Jacucci *et al.* [49], for instance, compare the dichotomy between designer and users in HCI to artist and audience in artworks. It is argued that the growing interest in participatory approaches to both art and design can blur these dichotomies. Artists may invite people to contribute within a given conceptual framework, or they may encourage the artwork to be ultimately appropriated and extended by the joint participation of audience and artist.

5 DISCUSSION

Because evaluation is a central aspect of HCI, there is already a vast amount of knowledge on the subject in the literature and among HCI researchers and practitioners. Nevertheless, the HCI community could always benefit from novel perspectives on the subject. On the other hand, there is a growing interest from interactive art practitioners in evaluating their work. This apparent alignment of interests may allow the evaluation to serve as a common ground for collaboration between the fields. Classical HCI evaluation methods, however, do not seem to be useful, neither well accepted, in the context of art. Their focus on well-defined goals and objective metrics seems out of place in the evaluation of interactive art, which is noticeable as both presented frameworks are heavily focused on experience. In contrast, evaluation methods focused on aspects of UX and aligned with third-wave HCI methods are already being appropriated by artists and used with relative success in some contexts [2, 6, 8]. How artists may appropriate, apply and evolve these methods is of high interest of HCI research as well, as it brings novel approaches and different views the HCI community alone could not be able to devise or envision.

Candy's evaluation framework, for instance, seems aligned with problem clarification methods that already inhabits HCI research for quite some time. As an example, Organisational Semiotics' Problem Articulation Methods (PAM), commonly used in Baranauskas' Socially Aware Computing (SAC) approach [4], similarly makes use of specific artifacts to elucidate problems. With proper epistemological and methodological considerations, an articulation of these two approaches may yield novel insights into projects with or without artistic intent. This line of inquiry, however, may also lead to a possible conflict between the traditional individualism of the creative process in art against the participatory nature of the SAC approach, *i.e.*, authorship vs. co-authorship.

Costello's pleasure framework, in turn, could benefit from the Pleasure, Arousal, Dominance (PAD) emotional state model used in HCI practices. The pleasure framework's categories seem to be associated with the pleasure dimension in the PAD model; it also seems to encompass the arousal dimension, as the authors argue

that some aspects of arousal of play act as modifying variables to the categories. This alignment with the PAD model may, perhaps, allow the use of well-established evaluation instruments alongside the framework, such as the Self-Assessment Manikin (SAM) [11]. Also, understanding the role of pleasure in interaction design may be an important tool for encouraging engagement, collaboration, and other desired aspects in projects with or without artistic intent. For that, the study of Tan and Ferguson [70] on the role of emotions in art evaluation may also provide further insights. Furthermore, some categories from the pleasure framework may be correlated with aspects already familiar to some HCI researchers. For instance: certain levels of *creation* can be considered to elevate the audience to the status of co-authorship, resembling aspects of Participatory Design; the amount of pleasure from *difficulty* can be analyzed from a perspective that combines the often fragile balance between motivation and ability; *competition* and *sympathy* may both involve and shape cultural aspects and values from the people involved; *sensation* can be explored from a Universal Design perspective; and *simulation* has much potential in the field of virtual reality.

We have already explored Costello's pleasure framework in the contexts of HCI computer science undergraduate and graduate courses [30, 31]. In these courses, we experimented with the approach of inserting art as a context for the discipline's main project. As preliminary results, students expanded their understanding of art and HCI and explored novel forms of interaction by creating projects around the concept of interactive art or installations. Students were also able to make sense of Costello's pleasure framework while they used it to evaluate projects from colleagues in a peer review manner and to inform the design of their projects. To further report these case studies is beyond the scope of this paper, but it shows both applicability of the framework and how the classroom may be a useful medium to promote the articulation of art and science, reaching not only the HCI community but perhaps widely and openly Computer Science itself.

Lastly, we did not find in the literature interactive art design and evaluation efforts that give emphasis to accessibility or Universal Design. This seems to be a missed opportunity as interactive art has an excellent potential for multisensory approaches (*i.e.*, unlike a painting or a sculpture you are not allowed to touch, interactive art can be designed to not rely too heavily on sight by, for instance, also promoting other senses such as touch and hearing.) Some of the projects we designed and built with undergraduate and graduate HCI students already have a higher attention to accessibility, but this remains an open opportunity for research. Furthermore, another possible direction to explore the subject of evaluation at the intersection between art and HCI is to revisit the practices of art critique and curatorship, which are usually not conducted by the artist itself, from an HCI perspective.

5.1 Towards a Research Agenda

Informed by what we presented and discussed so far in this paper, we consider the following recommendations as essential steps towards articulating art and science in HCI through the concept of interactive art:

- **Encourage interactive art research:** there seems to be a steady increase in publication numbers relative to the intersection between interactive art and HCI. However, there will always be numerous unexplored possibilities, and the potential mutual benefit for art and science seems to be a motivation to encourage further research on the subject. HCI communities could benefit from being open to works that permeate this frontier between the fields. Even though this could incur in some controversies regarding what is a valid scientific contribution in HCI (from conflicting ontological perspectives to different forms of rhetoric), these discussions could play an important role in contributing to the maturity of communities and openness to new ideas.
- **Study interactive art examples:** there are many interactive art approaches to be found in scientific literature and other sources from digital games to online communities, and this paper only scratches the surface in this regard. Sometimes these artworks are not even intentionally designed as or named interactive art by their authors, but the lack of artistic intent does not prevent them from being perceived as art. Nevertheless, interactive art examples can provide useful insights that can inform the design of digital artifacts with or without artistic intent. Our examples of interactive art, for instance, show a varied collection of interaction approaches and desired qualities for interactive systems that, with proper study, may also be achieved to some degree in non-artistic contexts. The embodied ways in which we can interact with art, for instance, can be applied to the design of IoT systems for smart homes and other environments that go beyond a dashboard controlled from a smartphone, and detect and respond to our physical presence and actions.
- **Practice interactive art design and evaluation:** theory on interactive art cannot be considered complete without practice, and it is the very practice of interactive art that resonates well with the field of HCI, providing a mutual benefit relationship. Furthermore, Cressey [23] argues that we are entering the “age of the arduino”, supported by data on how such devices are transforming science regarding automation and data collection. Besides their low cost, these devices are relatively simple, allowing its use by people without expertise on the subject, *i.e.*, there is no need to be an engineer or a computer scientist to use them successfully. Therefore, Arduino boards and the Raspberry Pi can serve as an inexpensive technical playground for people to explore interactive possibilities, whether they may be called interactive art or not. By exploring these technologies with a playful attitude, one can emerge significant learning experience and useful insights that could otherwise not be attained. Evaluation, in turn, complements the practice of interactive art with direct contributions to both interactive art practitioners and HCI researchers, serving as a common ground between the fields. The extensive evaluation knowledge from HCI can be borrowed, employed and deconstructed by interactive artists, which in turn can contribute to unconventional insights and approaches to evaluation. One possible way to foster the practice of interactive art design and evaluation is to conduct design projects about the subject in undergraduate and

graduate HCI classes, such as the InterArt [30] and InstInt [31] projects we have already conducted and reported on.

- **Design interactive art for all:** people should be able to experience interactive art regardless of their age, size, ability or disability. The open-ended nature of interactive art can be explored to push the boundaries of our understanding of accessibility and universal design both in terms of social critique, as well as in making use of multisensory approaches with different technologies of sensors and actuators. Tactile and sound feedback, for instance, can be used to not only complement visual features, but also to open entirely new ways and possibilities to experience interactive art artifacts altogether, artifacts, in turn, that can be experienced to the greatest extent possible of people. The design of interactive art for all can be approached both from “bottom-up” or “top-down” perspectives: you can make universal design a goal from the start, and conduct every design activity with universal access in mind, or, by exploring current technologies and prototypes, you may obtain insights about how these can be used to allow people with some limitation or disability to have a better experience.

6 CONCLUSION

The articulation of art and science can be a source of innovation in the interactive systems domain, and HCI can have a mutual benefit relationship with art through interactive art. Looking back at our first research question, interactive art can be considered a source of innovation regarding unconventional forms of interacting with a computer. We highlighted four distinct interaction approaches found in interactive art in the literature and other sources. These approaches (virtual, embodied, tangible and social) are illustrated with examples that contain useful qualities that may also be desired in computational systems without artistic intent. For our second research question, evaluation can be used as a common ground between HCI and interactive art practitioners. There are useful frameworks in the literature to support the design and evaluation of interactive art, such as Candy’s and Costello’s.

Although it is plausible that these could also be used in other contexts without artistic intent, there is still room for studies mixing them to some HCI practiced methods. Participatory approaches also provide unique ways of designing interactive art, providing a different perspective on the participatory design itself. The discussion on the results of these research questions leads to encouraging interactive art research, studying interactive art examples, practicing interactive art design and evaluation, and designing interactive art for all, as essential starting points in a research agenda.

Ongoing work involves the articulation of art and science in HCI by following the research agenda we outlined. More specifically, we are conducting work on the design of interactive art in a socially aware manner [4], and with a coupled relation between body and environment as described in the Enactive approach by Varela, Rosch and Thompson [72]. We expect this articulation to lead us towards the conception of what we may call socioenactive interactive art.

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