Designing Interactive Sonic Artefacts for Dance Performance: an Ecological Approach

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ABSTRACT

In this paper, we propose to consider the sonic interactions that occurs in a dance performance from an ecological perspective. In particular, we suggest using the conceptual models of artefact ecology and design space. As a case study, we present a work developed during a two weeks artistic residency in collaboration between a sound designer, one choreographer, and two dancers. During the residency both an interactive sound artefact based on a motion capture system, and a dance performance were developed. We present the ecology of an interactive sound artefact developed for the dance performance, with the objective to analyse how the ecology of multiple actors relate themselves to the interactive artefact.

CCS CONCEPTS

• **Human-centered computing** → *Interaction design process and methods*; *Empirical studies in interaction design*; • **Applied computing** → **Sound and music computing**; **Performing arts**.

KEYWORDS

Sonic Interaction Design, Artefact Ecology, Dance, Composed Instrument, Design in Use, Design Processes

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1 INTRODUCTION

In the last few decades, many interactive music systems for dance have been developed from both a research [11] and artistic perspective [18]. Contemporary dance performance scenarios can be composed of complex ecologies, that usually comprise a choreographer and several dancers as main actors. In such a multilayered context, each actor relates to a technological artefact, including interactive sound systems, in a different manner, developing a personal relationship with it based on the specific needs of her role. Another important element of a dance context is that an interactive sonic artefact is normally an integrated aesthetic component: the interactions and sounds are aesthetically part of the piece itself.

Based on this, we propose a method to understand and study how the different actors influence the design process of an interactive sonic artefact for contemporary dance. In particular we present a way of using Actors, Roles, Contexts, Activities, and Artefacts (ARCAA) [24], a framework to analyse artefact ecology and the relation among different actors in the same (computer music) performance combined with the Didactic-Democratic model by Butterworth [7]. Butterworth describes the possible forms of relation between dancers and choreographer in the Didactic-Democratic model, presenting a set of possible forms of collaboration among dancers and a choreographer [7]. ARCAA was initially designed to analyse the artefact ecology, the actual use of musical artefacts in the context of music performance, not a design process. To this end, we integrate ARCAA with the idea of a design space [5], and the type of collaboration between choreographers and dancers [7]. In this paper, we used these combined methods to analyse a case study with two dancers, one choreographer and one sound designer. In the study we combined the different models, and we argue that such a combination can be used in other studies, to help sound and interaction designers to understand the ecology of the dance performance. Based on our study we also present some design insights.

2 HUMAN ACTORS AND ARTEFACT ECOLOGY

During the last decades, computing has been spreading in many aspects of human life. As a consequence, researchers started to consider people as complex human beings rather than merely system users [2]. People have a broad set of motivations, values, goals and interests that should be considered when designing interactive systems. Building on this view, Bannon [2] proposed a switch from the concept of *human factors* to *human actors*.

Similarly, limiting the focus to the interactions that occur between one person and a single digital artefact may not be sufficient to frame an overall activity that is highly determined by the context. To tackle interaction from this broader perspective, Dourish promoted in-situ observations, helping to focus on a "detailed analysis of actual practice" [15]. By developing upon ethnomethodology, the author conceptualized the idea of technomethodology, promoting the analysis of actions "moment-to-moment" [15].

Another relevant concept to analyse the context of the interaction is the definition of design space by Botero and colleagues [5]. The authors propose that "a design space is always actively co-constructed and explored by multiple actors through their social interactions with and through technologies and [that] the participating actors, resources, conditions and supporting strategies frame the design space available." To study such a space, the author proposed the "design in use" model, a framework composed of two dimensions: "Use-Create", and "What People Do". For the objective of this paper, the "Use-Create" dimension is particularly relevant. This dimension is composed of three main categories: 1) Reinterpretation: this category is at the "Use" end of the Use-Create spectrum, and expresses the possibilities of surpassing the defined uses of an artefact. 2) Adaptation: this second category, in the middle of the spectrum, implies a certain degree of flexibility in the use of the technology. 3) Reinvention: this category is at the "Create" end of the Use-Create spectrum, and is usually achieved when new functions are created.

To better account for the context, the concept of artefact ecology is also extremely useful [8, 22]. The word ecology, used to conceptualise the artefact ecologies, is derived from Gibson's work on ecological psychology [19]. Gibson advocated that the features of our perception are determined by our ecology and, therefore, should not be analysed in isolation. Following this conceptualisation, Jung et al. proposed that a person's ecology of artefacts can be defined as the set of artefacts that a person owns, interacts with and uses [22]. A person's artefact ecology might include solely digital artefacts [4, 22]; or both digital and non-digital [8]. Recently, Erkut and Serafin [17] proposed the idea of sonic artefact ecologies to analyse the relation of sounds in different computational objects.

3 MUSIC TECHNOLOGY: AN INTERACTION DESIGN PERSPECTIVE

3.1 Composing by Making and Design Approaches to Music Technology

The creation of musical pieces and the development of new music technology have been intermingled in all western music history. This interconnection predates the digital era and finds its roots in the initial phases of development of western musical instruments. However, with the rise of electronic technology and its application to musical domains, the relationship between music composition and technology design has become even more interconnected as many composers started to develop their own music systems. Describing his practice Mumma declared: "I consider that my designing and building of circuits is really composing" (as cited in [29], chapter 5). With the spread of digital technology, and the growing interest around the design of new Digital Musical Instruments (DMIs), this tendency thrived. In early 2000, Schnell and Battier presented the Composed Instrument concept [30]: a musical artefact that embodies both the notions of the score and an instrument. Following a similar conception, Cook suggested: "make a piece, not an instrument" [13]. In general, the distinction between DMI and composition is often blurred [23].

A direct consequence of this trend is that the roles of the designer/developer, composer and performer are often played by the same person. As illustrated in a recent survey by Morreale and colleagues, four out of five NIME (New Interfaces for Musical Expression) practitioners self-developed their own instrument, of which they are the sole players [27]. From a design perspective, composing by making is very close to autobiographical design. In this form of design research, the researcher draws "on extensive, genuine usage" of the system he developed [28]. Recently, the autobiographical design approach has been directly discussed in a study by Turchet, who developed a smart mandolin "according to the paradigm of autobiographical design" [32].

Different design methods to design musical systems have also been used. User centered design [1], for instance, has been used to target specific populations of practitioners. Notable examples include the development of tools for audiovisual performers [14], and haptic tools for visually impaired audio producers [31]. Such an approach assumes a distinction between the designer and the target user. Normally, the artefacts resulting from such design processes are not representing a specific aesthetic identifiable with one artwork. On the contrary, such systems are tools that can be used in many situations. Another approach is represented by idiographic design, a form of "interaction design that focuses upon responding to detailed personal accounts of individuals' practices" [21]. Hook et al. applied idiographic design to design an interactive artefact targeting the needs of one audiovisual artist [21]. Exploring a co-design form of collaboration Masu and Correia proposed the idea of co-created composed instrument, underling the fact that the final musical choices where part of a negotiation process between the composer an the performer [25].

In the case of dance, the performer(s), the sound designer, and the choreographer (who is also the main author of a piece) are usually different persons, but still, interactive sonic artefacts embeded all the aesthetic features of the musical components of the piece itself. For this reason, we argue that this context offers a valuable opportunity to investigate music technology design.

3.2 Music Technology and Ecology of a Performance

A few scholars used the concept of performance ecology, as a manner to analyse electronic music scenarios [20, 24, 33]. For instance, Waters analysed a number of works focusing on contiguities among composition, performance, instrument and environment [33]. Another perspective is proposed by Gurevich and Treviño, who proposed to consider the music ecology and to consider the complex interconnections of human and non-human agents that occur in electronic music performance [20]. The authors advocate overcoming the clear-cut distinction between the roles of composer and performer, and proposed a more fluid conception of the different roles involved in a music performance ecology.

Recently, Masu and colleagues [24] pushed the analysis of music performance ecology further by combining music technology design literature with the concept of artefact ecology, proposing a framework entitled ARCAA (Actor, Roles, Contexts, Activities, and Artefact). The framework is composed of three main layers (roles, contexts, and activities) that connect each actor to the different artefact of a performance (figure 1). The first layer analyses the role (e.g. composer, developer, instrumentalist); each actor can play different roles while performing different actions. The second layer addresses the context. The framework suggests two main contexts: the rehearsal/creation (Off Stage) and the performance itself (On Stage). The final layer analysed activities, by listing all the actions that each actor plays in each context in relation to the artefacts.

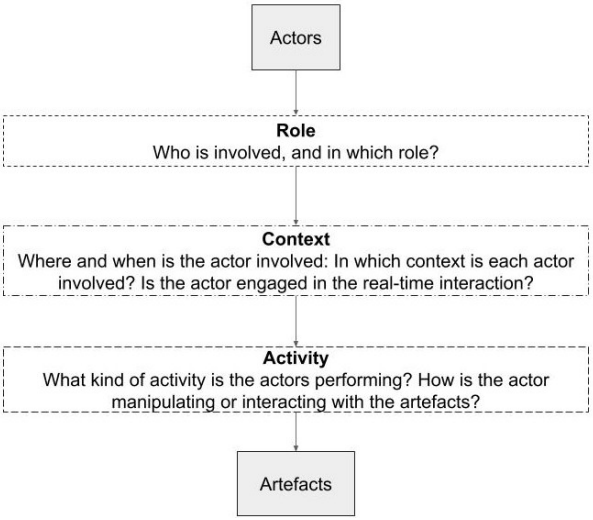

Figure 1: The ARCAA framework as in [24]

4 DANCE ECOLOGY AND INTERACTIVE SOUND

4.1 Dance Ecology

There are very different forms of dance coexisting at the present, for example, classical ballet, contemporary dance, physical theatre, dance and technology and so forth. Within each dance genre, working methods and roles taken on by dancers and choreographers can differ widely. In some genres, dancers might be asked by choreographers to improvise and thus participate in the creation process of a dance piece. Butterworth has examined different degrees of freedom for improvisation in dance rehearsal and performance ecologies [7]. In her Didactic-Democratic spectrum model, she distinguishes five kinds of processes. The choreographer can play the role of the "expert", "author", "pilot", "facilitator", or a "co-owner", while the dancer can be an "instrument", "interpreter", "contributor", "creator", or a "co-owner". At one end of the spectrum, the choreographer (as expert) controls every aspect of the creation and the dancer is merely an interpreter. At the other end of the spectrum, the choreographer (as co-owner) involves the dancers who are also co-owners at all stages [7]. In dance and technology setups the roles and tasks can become even more complex. Dancers, for example, have to be aware of the characteristics of the interactive artefacts and the media output they create through their movement. Birringer has consequently stated that there is a need for specific performance techniques for dancers in these ecologies [3].

4.2 Interactive Sonic Artefacts for Dance

Recently, several researchers, combining HCI and music computing, have investigated methods and techniques to develop technology to create music from body movement and dancers. A notable example on how to extract information from the body is represented by the work of Camurri et al. [9, 10]. Other examples studied how to map expressiveness in gesture with sound [12]. These works tend to focus on information retrieval, mapping or similar aspects and successfully developed design methods or frameworks to develop the technology itself. However, there has been a lack of focus on a broader perspective on the context of the use of such systems and the relation among the different actors in a performance ecology.

In the few years, some studies have addressed the relation among the different actors involved. For instance, in a recent study on a full body musical instruments for dancers, Erdem et al. report on the different perspectives of the musician and of the dancer [16]. Another example is presented in [18], describing the different perspectives of the various actors involved in a dance performance.

With this paper we aim at pushing forward this ecological perspective by proposing an analysis that combines different models and frameworks from computer music, interaction design, and dance. In particular, we will focus on how actors relate with the interactive sonic artefact, and how the different actors influence a design process and the final result.

5 OUR CASE STUDY: AN ARTISTIC DANCE RESIDENCY PROJECT

As a case study, we present a work developed during an artistic residency developed in the frame of the project Moving Digits (https://movingdigits.eu). The residency consisted of five sessions (each lasting for approximately 6 hours) with a performance at the end, and took place at Sõltumatu Tantsu Lava (STL) in Tallinn. During the residency, a choreographer had at her disposal a team of two media designers, one for the development of an interactive sonic artefact (the sound designer, first author of this paper), another one for the development of interactive visual content (a visual artist, third author of this paper), and two dancers. The choreographer (Hanna Pajala-Assefa) has considerable experience in working with interactive technology to generate sound from a dancing body. The two dancers (Madli Paves and Christin Taul) have international experience in contemporary dance, but no previous experience with interactive technology used to generate sound from the body. Figure 2 shows the choreographer and the two dancers in the rehearsal space. For the scope of this paper, we will not account for the visual components. Sound-wise, the final piece was composed of three main scenes, each corresponding to a different interactive setting, plus an intro. In this paper, we will considered the three main scenes.

5.1 Methods: Data collection and Analysis

Following the technomethodology approach proposed by Dourish, the sound designer collected field notes and interviews during and at the end of each session aiming to analyse how the different actors relate to the technology "moment by moment" [15]. At the end of each of the first four sessions, the sound designer interviewed the choreographer, and at the end of the residency, the two dancers. The fifth session was only focused on rehearsing the piece. We used semi-structured interviews. The questions to the choreographer focused on how she collaborated with the rest of the team and the relations between the development of the performance and the technology, and lasted between 8 and 20 minutes. The two dancers were interviewed together, and the joint interview lasted 16 minutes, with questions focused on how they interacted with the technology, in each of the three different settings that we developed. We present the interview results independently for each of the three scenes. The direct quotes are presented in italic between quotation marks, the choreographer is abbreviated C. while the two dancers are abbreviated D.1 and D.2. We coded the interviews to understand how the dancers relate to the technology in the different moments of the performance. The interviews were analysed using thematic analysis [6] by the sound designer. In the final analysis with ARCAA, the sound designer also introduced his autobiographical perspective.

The field notes were used to reconstruct the activities in the different sessions. In the organization of the field notes and of the analysis of the interview of the choreographer, a clear distinction emerged: between the first two sessions and the following two. For this reason, we clustered the sessions in two phases: co-creation/design phase and fine-tuning/rehearsal phase. The design of the artefact was mostly concluded in the first phase.

Figure 2: From the left: he chreographer Hanna Pajala-Assefa, and the two dancers (Christin Taul and Madli Paves), discussing the piece in the rehearsal space.

5.2 Technological Setting

The interactive sonic artefact was implemented using a motion capture system as input to generate audio from the body movements of the dancers. To capture body movements, we used a RGB computer vision-based markerless motion capture system named Captury[1]. Our Captury set-up used 8 cameras to extract human skeleton data, offering a non-intrusive approach to track multiple persons' full-body movement. This approach was based on requirements gathered from dancers and choreographers in a previous stage of the Moving Digits project [26]. We extracted the coordinates of 12 skeleton points and the overall amount of movement of the dancers. The audio engine in this context was developed using Pure Data Vanilla[2]. The final interactive sonic artefact for the performance consists of three different settings each with a specific mapping strategy to generate different sounds from the movements of one or two dancers on stage. The three settings correspond to the three main different scenes of the piece. The design is further detailed in the next section.

6 RESULTS

In the following sections, we present an overview of the activity of the four first sessions (the last session mainly focused on rehearsing the piece), and the results of the data analyses. The activities were not predefined, rather we adapted the procedure to the needs emerging in each session. In the two phases, we present the observation collected by the sound designer, and the results of the interviews with the choreographer and the dancers. The dancers' perspective is present only in the fine tuning phase. The information extracted from the field notes of the sound designer are selected to 1) give an overview of the activity, and 2) highlight the relationship between the different actors and the artefact

6.1 Co-Creation/Design Phase

6.1.1 Description and Observation from Field Notes. In the co-creation/design phase we implemented three main instruments that corresponded to the three main scenes in the dance piece, which were developed in parallel.

The first instrument was characterized by a crackling sound whose volume and crackling density was mapped to the movement amount. The amount was calculated using a computer vision approach and computed by subtracting two sequential frames of positional data generated using the information coming from the motion capture system. The crackling sound was implemented using a set of variable time delays reading in different points at variable speed a percussion sound store in a buffer, resulting in a granulating effect. This instrument was used in the first scene, and the choreography consists of an open task: D.1 was required to improvise alternating movements with moments of stillness. In the same scene, the second dancer (D.2) was required to imitate the first dancer's static pose.

The second instrument we implemented was a percussive sound that was triggered by dancers' hand movements. Initially it was triggered when the dancers' hands were closer than 10 centimeters to the floor. This sound and the interaction were subsequently improved by changing the interaction: a hand-clapping gesture would act as a trigger. These changes were based on the observation that the choreographer made by seeing the dancers interacting with the system. We also added some delays and reverberation to these

[1] https://www.thecaptury.com/
[2] https://puredata.info/

sounds. The sound was similar for the two dancers but the actual pitch and timbre of the two sounds were different, so each performer had her own sound. This was used in the second scene, where the choreographic task was to maintain a continuous movement.

The third instrument was a cello drone. The volume of the cello was directly mapped with the average movement amount of the two dancers, calculated by using the same approach developed for the crackling sound. This instrument was used in the third scene. In this scene, the choreographic task was to explore the body of the other dancer, by grazing it with any body part while maintaining a continuous movement. As a consequence, the two dancers shared an intimate space, mutually influencing their movements.

In the first phase, the choreographer tried the hand-clapping interaction for the percussion herself. She also tested the choreographic tasks with the dancers, and modified them according to the feedback. In order to test the threshold of the percussion on the floor and the crackling sound, the sound designer asked the dancer to perform specific movements.

6.1.2 Interviews - Choreographer. In this phase, we identified four main themes, some with sub-themes.

Dance and technology mutually influenced. Overall the most important element that emerged is how the development of the technology and of the choreography were strongly interconnected and mutually influenced: the entire work was a "*negotiation between the dance and what the technology offers, and how do we use it artistically,* [... a] *negotiation between all the elements.*" C. Therefore the process goes in two directions: "*Both changing the technology to adapt to the dancers and change the* [choreographic] *task to adapt to the technology*" C.

Audio not merely doubling. This was the general design principle that we followed and was led by an artistic need, in our case "*audio not doubling,* [not] *giving the same information as the visuals*" C.

Choreographic task derived from technology. The choreographic tasks are adapted to the technology, "the technology and the task is intertwined all times" C. The objective was to "*create a situation where the dancers can really do their job as a dancer, but also there is an additional awareness level* [...]. *It's really changing the choreographic task or the attitude of the dancer*". This has also a practical implication: "It was easy to start with just one dancer in the Captury, just to define how it sounds, and how it moves" C.

Sound is sensible. According to the choreographer "*working with the sound is more time-sensitive*" C. as it requires time to feel it, and to explore the possibilities.

Sound designer as a collaborator. The sound designer was perceived as a collaborator "[this is] *an artistic collaboration and* [...] *not only technical tasks.*"C. But also supporting the process practically: "*because I can't do everything,* [...] "*pay attention to everything simultaneously*" C.

Open instructions to the dancers. The choreographer gave tasks to the dancers that were quite precise about the general frame but also provided space for improvisation."*The* [dance] *situation is structured*" C., but also "*the tasks were* [...] *open or improvisatory.*"C.

6.2 Fine-tuning/Rehearsing Phase

6.2.1 Description and Observation from Field Notes. After session 2, the main design features of the final artefact were concluded and defined in the three instruments ('crackling sound', 'percussion', and 'cello'). The sonic features were fine-tuned: the delay time in the percussion, the timbre of the cello (we added a second sound, one octave lower, to the cello). In this phase, we also fine-tuned the calibration of the motion capture system. This activity included a specific work with the dancers: the sound designer required them to perform specific movements to test thresholds. The sound designer also explained to the dancers the functioning of both the motion capture system and the sound computing engine.

During the fine-tuning process, the dancers became more aware of the motion capture area and of how their movement influenced the sound. Apart from these minor sound details and system calibration, the last sessions focused mainly on the development and rehearsal of the choreography.

6.2.2 Interviews - Choreographer. In this phase, we identified three main themes.

Peer collaboration among everyone. In this final stage of the residency, the collaboration was "*more a peer discussion*" C: "[the dancers were] *able to give feedback because they know how it is supposed to go.*" It is worth noticing that in the previous phase this was not the case.

Learn to play. In the final stage, there was a need to give time to the dancers to acquire confidence with the interaction: "*They have to get confident, learn to play" C; "It's essential for the work* [...] *that the dancers understand* [...] *what* [their actions] *affects, and what to avoid*" C.

Technology Adaptation and Fine Tuning. At this stage, there was a need to adapt the interaction design to the actual physicalities of the dancers: "*it's essential* [...] *to have these fine-tunings*" C.

6.2.3 Interviews - Dancers. In this section, we present how the dancers relate themselves with the technology in each specific scene. From the interview, we identified one different relationship (theme) with the technology in each scene. In the second and third scenes, the two dancers had the same relationship with the interaction and the sound.

The sound affects the dance indirectly (first scene). D.1 reported that interacting with sound was changing her dance indirectly: "*it does* [change] *as a consequence of me thinking constantly of what my movement does because of the sound that I am creating*" D.1. For this reason, her focus was not only on the dance: "*I have to divide my attention* [...]. *I am slowing down my movements* [...], *just to make sure that the sound is coming along with me.*" D. 2, who was not controlling the sound, did not pay attention to it.

The interaction changes the dance (second scene). Both dancers were primarily affected by the fact that the hands were triggering the sound. "*I know that my hands are the trigger, so I put a lot more attention there, even the posture of my body*" D.1. "*I can say that my movement starts from the hands, because I am super aware of them*" D.2. There was also a feedback loop "*the sound influences the movement back*" D.2., especially the delays and the reverberation, changed the way the dancers moved.

Ignoring the sound and the interaction (third scene). In this last scene, the sound was not the main focus of the dancers, because the choreographic task (exploring the other dancer body) was overwhelming. "*I think for me here the task is superior to the sound itself.*" D.1. "*The task is over everything*" D.2.

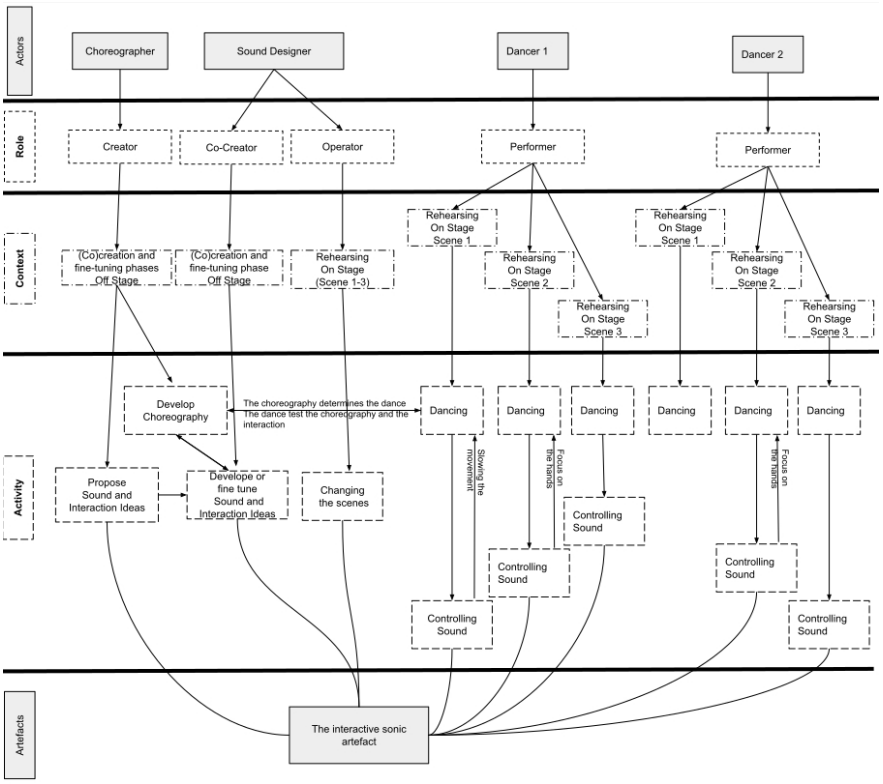

Figure 3: The overall ecology represented by using ARCAA

7 DISCUSSION

7.1 ARCAA and the Overall Ecology

In the previous sections, we presented the residency and the results of the data analysis. Overall, we have observed 1) how the design of a system and the design of the choreography were mutually influenced, and 2) how the interaction design was fine-tuned according to the actual movement of the dancers. We now present the overall ecology in a graphical form using ARCAA [24]. The graphic highlights the interconnection of the different actors (figure 3).

ARCAA helps to visualize how the choreographer and the dancers mostly operate in two different contexts. From the graphic, we can observe how the choreographer is involved in Off Stage, in a creation process, while the dancers are involved On-Stage, therefore in the actual interaction. It is also worth noticing that both co-design and fine-tuning are activities that occur Off Stage and that the dancers are involved in both the testing (influencing in the co-creation and the fine-tuning) and the interaction (while rehearsing or performing). So the fine-tuning/rehearsing phase can be further separated using ARCAA according to the perspective of the different actors.

In the activity layer of the graphic, we can see how the design of the system and the creation of the choreography are interconnected, as highlighted by the loop between dancing and developing choreography activity. Using the words of the choreographer: the process implied "*both changing the technology to adapt to the dancers and changing the task to adapt to the technology*" C. Concerning the main activity of the performance (dancing) we can see how many different elements influence it. Primarily, the dancers were given a choreographic task that was quite prescriptive, but also left space for personal interpretation and flexibility to adapt it to the interaction with the technology. In our case study, the choreographer was instructive with the dancers, but also left space for improvisation. This corresponds to the third category in the Butterworth collaboration model: choreographer as pilot - dancer as a contributor [7]. Indeed, even though the dancers are mainly following a choreographic task (developed by the choreographer), the interaction with the artefact influences their dancing, and the dancers have space to explore the task according to the interaction (scene 1 and scene 2). In other cases (scene 3), the dancers adapted the interaction according to the task. The graphic highlights how each scene represents a different context for the dancers. Indeed each scene has a different feedback loop between controlling sound and dancing. For instance, in scene one, D.1 was "*slowing down* [her] *movements*", in scene two their "*movement starts from the hands*" D.2, while in scene three the choreographic "*task is superior to the sound itself*" D.2. We hold that a sound designer should be particularly careful to address these interactions.

ARCAA also helps to visualise the autobiographical perspective [28] of the sound designer , and how he played two different roles. As emerged in the interview with the choreographer, the sound designer was a co-creator/designer in the design phase; he was also an operator during the performance.

7.2 Account for the Needs of the Different Actors (Insights for Sound Designers)

In our case study, we observed how the choreographer and the dancers have different needs. We suggest that both have the same level of importance that should be taken into account in the development of an interactive sonic artefact. As a general principle, we suggest to consider the complexity of the ecology of a dance performance and how multiple people mainly play different roles (choreographer - dancer) and operate in distinct moments (such as co-creation/design phase, fine-tuning/rehearsing phase, performing). The choreographer has general needs related to the artistic ideas of the dance piece, while the dancers have needs related to the actual interaction.

Based on our study we highlight some elements concerning interactive sound design related to the needs of the different actors:

- The technology development and the choreography are mutually influenced, this affects the way of working: "*both changing the technology to adapt to the dancers and changing the task to adapt to the technology*" C.
- A choreographer might need extra time to work with sound to fit in the aesthetic of the piece: "*sound* [requires] *more time to stay on it, and feel it, and to explore the different possibilities* [...] *it needs a special time.*" C.
- There might be a need for the dancer to "*get confident, learn to play*" C.
- The dancer would need to understand the functioning of the system: '*It's essential for the work* [...] *that the dancers understand what effects from their movement*" C.

7.3 Co-Creation and Composed Artefacts

In our case study, we observed how the creation of the choreography and the development of the artefacts unfolded as parallel elements of the same activity. Therefore, the final artefact embeds the aesthetics of the sonic components of the dance piece itself, and at the same time, the piece could not be performed without the artefact. The artefact is also an instrument, as it can be "played" by the dancers. This characteristic is aligned with the multitude of cases in which an interactive sonic artefact is designed for one specific performance, and therefore can be considered a composed instrument [30]. From this perspective, we followed Cook's suggestion "make a piece, not an instrument" [13].

In the Composing by Making section we have seen how the creation of new musical instrument/interactive sonic artefact overlaps with the act of composing [23, 30]. In most cases, the same person is the designer of the instrument, the author of the piece (composer), and the performer [27]. The case that we analysed presents a situation where the three roles are played by different people but still the technological artefact embeds the aesthetic of the piece. We argue that the interconnection between these three roles needs to be carefully considered during a design process. Mumma's sentence "building of circuits is really composing" [29], could be adapted to our case study: co-developing the artefact is really co-composing the soundtrack of the dance piece, and (co-)creating the choreography. For this reason, based on the idea of composed instruments [30], we suggest the term co-created composed artefacts, to reflect on the complex ecology of a dance performance.

7.4 ARCAA and the Dance Design Space

In this section, we combine ARCAA [24] with the "design in use" framework by Botero and colleagues [5] to analyse the design space of our case study, and better frame the different level of interconnection in the "design in use" model. In our case study, we have seen how the choreographer mainly operates in an Off Stage context, and the dancers operate on stage. Referring to the "design in use" model, the reinvention category (design) reflects mainly the activity of the choreographer, especially in the first phase (the co-creation/design phase). In this phase, when the system is actually invented, indeed, the choreographer led a process. We can see the design as a process of reinvention of the use of the motion capture system, that lead to the invention of the three instruments, as well with the choreographic tasks. In the second phase (fine-tuning/rehearsing phase), the activity of the choreographer is less strongly connected to the invention category, but rather it reflects an adaptation attitude, where both the system and the choreographic task are refined. The reinterpretation category by Botero reflects the perspective of the dancers, who are interpreting their choreographic task, according to the confidence that they gained with the system. Combining this observation with ARCAA, we suggest that the Off Stage context (where the choreographer is) mainly corresponds to the invention, and partially to the adaptation categories of the "design in use" model by Botero, while the On Stage context (where the dancers are) mainly reflects the interpretation category.

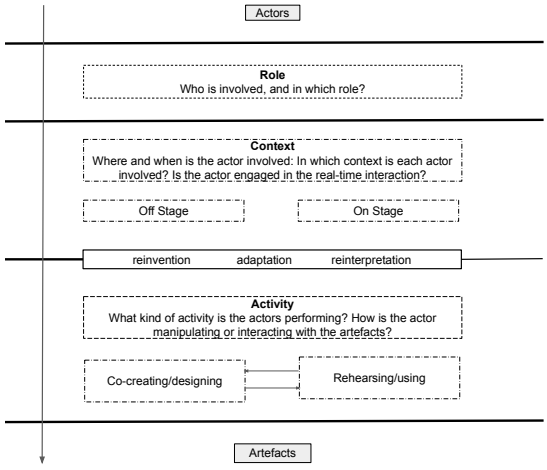

Figure 4: The ARCAA with the "design in use" model

Using ARCAA in our case study, we distinguish between the co-creation/design phase (Off Stage) from the use phase (On Stage) when dancers were actually interacting with the artefact, either in rehearsal or performance. These two phases correspond to the (re)invention and (re)interpretation categories of the "design in use" framework proposed by Botero [5], while the adaptation phase is in-between the two elements (figure 4). Compared to the original graphic of ARCAA [24], it highlights further the interconnection between co-creation and use, adding also horizontal connections.

7.5 Conclusion

The main contribution of this paper is an approach, which combines different theories, to understand the design and use of an interactive sonic artefact in the ecology of a dance performance. In the study, we highlighted the distinction between the two main roles of a dance ecology (choreographer - dancer) and how they relate with an interactive sonic artefact in two distinct moments (design - use).

We integrated ARCAA [24] with the "design in use" framework [5], and the Didactic-Democratic model by Butterworth [7]. ARCAA helps to visualize the different roles, context and activity of the different actors, and facilitates the understanding of the entire context. Combining ARCAA with the "design in use" model [5] allows to develop a deeper understanding of the relation between design (inventing) and use (interpreting) that occurs during a residency. Moreover, a link between ARCAA and the model by Butterworth [7] can foster a better understanding of the relations among the various actors. Different types of collaboration can lead to different connections among the actors in the ARCAA framework. Nevertheless, using such a combination can help to frame the context in which the different actors interact with an artefact, and what the final impact on the aesthetic of the performance is. For these reasons we support that our approach offers a way to apply idiographic design [21] addressing an entire scenario, and not just the individual needs of a single user. In addition, using ARCAA it is also possible to add the autobiographical perspective of a sound designer in the graphic representation of the scenario ecology.

We hold that the case study and the theoretical reflection presented in this paper could be useful to develop interactive sonic artefacts for dance performances. We hope that this paper will help other researchers and practitioners to better research other forms of collaboration by applying the methods discussed in the paper.

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