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NUAGE: A Digital Live Audiovisual Arts Tangible Interface

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Abstract

This paper presents a literature review rooted in Human-Computer Interaction research as the methodological basis for the proposal of a tangible interface called NUAGE. It is aimed at artists, performers and designers in the research field of Digital Live Audiovisual Arts.

Audiovisual performance combines musical and video arts together in a live artistic context. Tools to create such performances are often only software and do not provide the artists a wide range of interaction possibilities. A show where the performer's actions are hidden behind his/her computer screen can be visually less interesting. To provide guidance to designers and help them branch out from the traditional graphical user interfaces, we propose a different and structured design approach, Digital Live Audiovisual Arts, that builds upon Tangible Interaction concepts. We map Digital Live Audiovisual Arts by investigating its distinctive design intentions (expressiveness, performativity, participation, aesthetics and engagement) and proposing interface types taxonomy. To implement and validate this novel methodology, we developed NUAGE, an original performative interface. We thus bring together different perspectives on understanding Human-Computer Interaction and set a platform for future research on artistic tangible systems.

Figure 1: NUAGE interface prototype during audiovisual tests

Keywords

Tangible Interaction, Tangible User Interface, Digital Live Audiovisual Arts, Audience Experience, User Experience, Human-Computer Interaction

Introduction

Software-based music and video applications are widely used, easily accessible and have introduced new sounds and possibilities. However, a "Laptop Show", where the actions of the performer are hidden behind a screen, is definitively less interesting and comprehensive for an audience than seeing an artist perform with a complex instrument [25, 36]. As wittily highlighted by Klemmer et al., how can the audience know that *"the performer is not just checking his email?"* [23].

Aside from computers, new kinds of hardware tools have been developed to support and enhance audiovisual (AV) performers practice. Examples are the reacTable [21], the Live Cinema Instrument [25] and the uPoi [45]. Those interfaces seem to be a good alternative to laptops, providing more visibility and affordance to AV performances. However, hardware tools are not as easily accessible as software tools. Artists who make their own tools are often self-taught and may not have proper knowledge on how to build such interfaces. Moreover, there is a lack of scientific literature identifying the particular design requirements of AV instruments [30].

This paper addresses this problem by presenting a new promising approach, Digital Live Audiovisual Arts (DLAA). DLAA is a methodology that provides designers, artists and makers a structured understanding of the design needs of AV performative instruments. This, we hope, will foster research and design to branch out from the common computer interfaces and develop better suited and accessible interaction devices for both the user and the audience.

The following sections aim to map the novel DLAA approach. We start by defining its conceptual foundations to give the reader a better understanding of its main concepts. We then present the DLAA design approach by identifying the distinctive intentions that can be achieved using tangible interfaces as performative AV instruments. Next, we introduce the DLAA taxonomy to identify the different design implementation types.

In the last section of this paper we put the DLAA methodology into action. We present NUAGE, an original AV interface developed using the DLAA approach. NUAGE is an interface made to control audio and video content in a live, real-time context. A picture of the interface can be seen in Figure 1. NUAGE is aimed to be used by an artist during a performance in front of an audience. The prototyping of the interface allowed us to test and validate the DLAA method.

Digital Live Audiovisual Arts

DLAA is a novel design approach that builds upon Tangible Interaction principles to guide the development of AV performative instruments.

Tangible Interaction takes its roots in Ishii and Ullmer own updated vision of Human-Computer Interaction (HCI) [18] . In 1997, they introduced the concept of Tangible User Interfaces (TUIs). Different from the traditional Graphical User Interfaces (GUIs), where "painted bits" on a screen are controlled by a mouse, a keyboard or a tactile interface, TUIs aimed for a more engaging and seamless relationship with the digital world. Ishii's "tangible bits" concept focus on the physical representation of digital information, exploiting the richness of possible interfaces given by the "real" physical world [18].

Building upon those concepts, Hornecker and Buur Tangible Interaction framework focus less on the design of the visible interface but on the design of the interaction itself [11]. Apart from Ishii data-centered viewpoint on tangibles, their vision also includes action-centered viewpoints like movement, body and space centered interaction design. Tangible Interaction is an umbrella term describing an interdisciplinary research field encompassing HCI, Computer Science, Product and Industrial Design and Interactive Art studies, among others [12]. Hornecker and Buur described the characteristics of such systems and interfaces with four main design principles: tangibility and materiality, physical embodiment of data, bodily interaction and real space embeddedness [11]. The proposed model is thus based on these concepts.

The term "Digital Live Audiovisual Arts" is used in this paper in a nod to the term Digital Live Art (DLA) that was proposed in Sheridan et al. paper and described as *"the intersection of live art, computing and human-computer interaction"* [46]. By adding the "Audiovisual" term to DLA we bring together the notions of real-time AV performance, Tangible Interaction, Human-Computer Interaction, User Experience, computer-based art and artistic intent. DLAA has the particularity to combine different artistic design intentions such as expressiveness, performativity, participation, aesthetics and engagement under a single and common approach in cohesion with AV performances design requirements. Furthermore, it allows to study such intentions from the perspective of a direct user, the performer, and from the perspective of other people involved in the interaction, i.e. the audience.

Proposed Design Intentions Approach for Digital Live Audiovisual Arts

We present in this section our DLAA design approach structured by five main and distinctive design intentions: Expressiveness, Performativity, Participation, Aesthetics and Engagement. Those design intentions offer a wide perspective on the different goals a designer may want to achieve by developing AV performative instruments. While the design of Tangible Interaction systems has been studied before to pursue each of those intentions individually (examples are: [13, 21, 31, 37, 41, 45, 52]), DLAA has the particularity to bring all those key intentions together under a single and common approach that offers conceptual design guidance. Furthermore, it allows to study such intentions from a direct user's perspective and from an observer's perspective.

The five DLAA design intentions are defined in the following subsections. Examples and explanations on how they can be enhanced by Tangible Interaction guiding concepts are provided. Table 1 offers a summary on how those principles (physical embodiment of data, materiality, affordance, real-space embeddedness, bodily interaction) apply to the design intentions approach.

Expressiveness

Expressiveness can be described as the ability to transmit one's emotions and intentions through his/her action. Expression is achieved in various ways with TUIs.

By analysing VJ practice, Hook et al. identified how TUIs help the artist express him/herself. They identified themes linked to affordance, physicality and the importance of liveness in the practice [10].

Ross and Keyson developed principles for designing expressive tangible interfaces[41]. The context and the nature of the interaction, as well as the different physical properties of the interface can enable creativity and expression in various ways. The authors give the example of a door, which can be hardly slammed or softly closed to express different emotions. They also highlighted how expressiveness is subjective and that it may be experienced differently by one another. Therefore, such individualism should be considered, allowed and maybe enhanced by the interface.

Correia and Tanaka interviews with AV performers highlighted the fact that artists want *"to be able to make visuals "like a musician" and the desire to play an AV tool with the same expressivity and fluency as a traditional musical instrument."* [6] The fact that the interface must be easy to use and flexible is also a way to make it expressive. On the other hand, complex interface can allow the user to become skilled and therefore explore and be creative [10].

Performativity

Performance is another key concept of DLAA. Hornecker and Buur stated that:

"Performativity implies that the detailed HOW of doing something is an integral part of the action's communicative effect. [. . .] As an aside, performativity can be enhanced by tangible manipulation, as the material objects are visible as well and may require large movements" [11].

Table 1: Summary of the Digital Live Audiovisual Arts Design Intentions Approach

Design Intentions	Expressiveness	Performativity	Participation	Aesthetics	Engagement
Tangible Interaction principles	Affordance Physicality Liveness Individuality Complexity	Visibility Intuitiveness Unobtrusiveness Flexibility Intriguingness	Collaboration Modularity Controllability Understandability Multi-user	Attractiveness Enjoyment Resonance Coherence Appeal	Representativity Attention Involvement Usability Endurability

TUIs benefit to performance in various ways. Sheridan and Bryan-Kinns proposed guidelines on how to design interactive tangibles for performance [45]. Focusing on live and in-the-field performance, they iteratively design the uPoi and came up with six requirements. The design must be Intuitive (Responsive), Unobtrusive, Enticing (Visible and Attractive), Portable, Robust and Flexible (Controllable).

The studies of Correia and Tanaka showed that the majority of artists are concerned about whether or not the audience understands and feels the liveness of their practice [6]. The VJacket [53], was designed to enhance a VJ's performance, making his/her movement connected with the video and therefore more visible to the audience.

Paradiso explains how tangible modular synthesizer attract the audience in shows [34]. The researcher stated that the sight of such an intriguing and complex instrument fascinates the public, which is indeed great for a performance. Jordà also stated that the visual feedback given by the reacTable brings *"the physical performance back to live computer music"*[22]. This helps the public understand the performance.

Participation

The participation DLAA design intention illustrates the relation between different artists that perform and create together. Participation also highlights the importance of the relation between the artist and the audience. The following examples demonstrate how some particularities of Tangible Interaction can contribute to this intention.

Collaboration between artists

Like highlighted by Jordà, few musical instruments are multi-user, still, music is well known to be a group (or band) [22]. The design of TUIs can address this issue. The reacTable [21], is an example of novel musical instrument explicitly made to promote collaboration. Its multi-user and shared-control tabletop interface enhance participation. Many researches state that tabletops are well suited for collaboration and a lot of collaborative tangible tools are based on that same principle [44, 48].

The Polymetros [4] is another example of musical instrument that promotes collaborative music-making. Developed for a wide and novice public, it consists of several illuminated buttons panels connected to a central hub. The physical presence of the individual alike panels as well as their disposition around the central hub invites to collaboration. The authors identified that the "sense of control" over their own contribution is very important for participants in a collaborative process. Each participant must be able to easily identify what they individually bring to the performance and what other participants individually add too. This can be achieved with clear visual and audio feedbacks related with the participants actions.

Audience shift from spectator to performer

Tangibles can enhance audience participation in different ways. Discussed earlier, visual feedback can help the audience appreciate their experience. Another way to enhance their experience is by letting them be a part of the performance.

Sheridan et al. framework categorised the different stages of the audience involvement in a digital live art context [46]. They examined the transition between the audience's behaviors of "spectating", "participating" and "performing". Spectating can be described as a passive awareness that a performance is going on. The audience does not interact with the performance, is simply watching and might not understand what is going on. Participating starts when the audience engage with the performance, interacts simply with it even though they do not fully understand its frame. The performing stage arises when the audience has gained skills and understand the meaning of its actions. This is when the audience can start to express itself and be creative.

To favorize the transition from spectating to performing, it is important that the audience understand how they can interact with the performance. While testing the uPoi, Sheridan and Bryan-Kinns tried to rise the audience attention by costuming herself, making her prototype visually interesting and having experts already performing with the object [45]. Taylor et al. reported that the intriguing nature of their tabletop video instrument attracted the audience to come try and play with it[49]. To encourage participation, a clear, direct, real-time correlation must be understandable between the real-life interactions and the digital outputs of the TUI. Affordance here is the key; some materials, sizes and shapes might suggest different interaction ways and outputs than others.

Aesthetics

Aesthetic is the affective appeal, perceived beauty, attractiveness and enjoyment we feel for certain characteristics of objects [8, 33, 37].

Shaer et al. survey on tangibles identified aesthetics as a promising field of research in TUIs [43]. Some researchers focused on the aesthetics of the physical elements of tangible objects, others on the aesthetics of interactions. The authors stated that *"arts-based research often aims for a poetic aesthetic that goes beyond form"*.

Hummels et al. research on aesthetic tangibles focused on their resonant aspects [13]. The appearance of an object must be coherent with its use, its purpose and its feedback. Petrelli et al. studied how the aesthetics of hybrid objects are perceived by humans [37]. Objects mixing different sizes, shapes, materials and behaviours were evaluated to determine what impressions they gave to people. The researchers identified subjective attributes like "Interesting, Comfortable, Playful, Surprising, Pleasant, Special and Relaxing" to describe the objects. Their results show that certain aesthetics should be preferred to achieve certain impressions. Djajadiningrat et al. paper highlights that the visual appeal is not the only important aspect of aesthetics to consider when designing tangibles, the aesthetics of the interaction we have with the objects must also be considered [8].

Engagement

Engagement is the capacity of gaining one's attention or devotion, maintaining it and doing it for a long period of time [27]. Different factors constituting engagement are defined in O'Brien and Toms paper: perceived usability, aesthetic appeal, novelty, felt involvement, focused attention, and endurability [32].

In DLAA, we are interested in the artist engagement towards his/her tools and methods, but we are also interested in the audience engagement toward a performance in which the artist is using tangible digital instruments.

User engagement

Csikszentmihalyi flow theory [7] propose that continued immersion and enjoyment comes from the balance between skills and challenges in one's interaction. Building from this idea, the Wyeth framework [52] describes how the balance of TUI attributes, its representational and control qualities, leads to a more engaging use of tangible systems. As previously seen in the expressive design intention section, complexity and flexibility of interface controls are qualities desired by artists. Again, the role of a strong representation of the digital data, whether in a tangible or digital overlaying way allows for an affordable and intuitive understanding of the interface.

Audience engagement

Using appealing visible and comprehensible interfaces is also a good way to maintain the audience attention. In a laptop-based show, the audience may perceive the artist to lack of control over the occurring performance, due to his/her minimal or hidden actions. This can lead to a lost of interest and attention in the performance and therefore a lost of engagement [36]. Furthermore, encouraging the public to participate is way to make them feel involve in a performance. Those two ideas have been developed in the previous sections.

Digital Live Audiovisual Arts Interface Types

Building on previous categorisations of tangible systems[19, 24, 50, 51], the DLAA design approach proposes to structure the different tangible interface architectures possibilities in a way that applies more specifically to the peculiarities of AV performative systems. The following seven different interface types are proposed: Interactive surface, Constructive assembly, Token+constraint, Pressure-based interface, Wearable, Motion-based interface and Augmented common instruments. Figure 2 illustrates such concepts. We added the concepts of pressure-based, wearables and motion-based interfaces to the already existing notions of interactive surface,

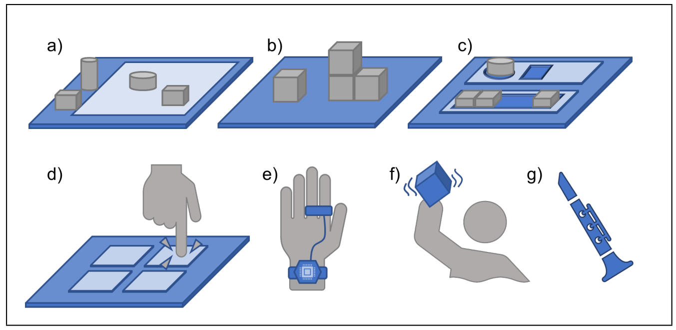

Figure 2: Loose illustration of different types of interfaces: a) Interactive surface, b) Constructive assembly, c) Token+constraint, Inspired by [51], d) Pressure-based interface, e) Wearable, f) Motion-based interface, g) Augmented common instrument

constructive assembly and token+constraint systems. Our last category "augmented common instruments" is similar to the "augmented everyday objects" one presented by Ishii but is adapted to AV instruments [19]. It is important to note that AV tangibles interfaces are not necessarily confined into those categories and can combine two or more types of architectures into one.

One goal of this categorisation is to highlight the wide set of design tools available to designers while creating an interface. It provides practitioners with an overview of the design possibilities within DLAA. This section will also highlight how certain types of interface foster the design intentions mentioned in the previous section (see Table 2). Thus, this will help designers to better communicate, justify and evaluate their design choices.

Interactive Surfaces or Tabletops

Typical tabletop tangible systems contain physical objects whose presence and movements are tracked on top of a graphically augmented surface [19]. Those types of tangibles are frequent in digital live arts, perhaps the most known example is the reacTable [21]. Other examples are the mixiTUI [36], the Audiopad [35], the Media Crate [3] and the VPlay [49].

Constructive Assemblies

This second type of interface is based upon building blocks and LEGO™. This architecture implies the modular construction of a system created by the physical connection of objects or by the near placement of such objects [19]. The AudioCubes [42] are one example of nearby constructive assembly. Digital modular synthesizer can be classed as constructive assembly. They consist of several different modules who have compatible hardware connectors, that when patched together enable various sounds. By adding different patch connections, the artist creates unique music. Building on this concept, block assembly mimicking the behaviour of modular have emerged like Block Jam [31] and the Patchblocks [28].

Table 2: Implementation types and their associated design intentions

Design intentions / Implementation types	Expressiveness	Performativity	Participation	Aesthetics	Engagement
Interactive surface			X		X
Constructive assembly	X	X			X
Token+constraint	X				X
Pressure-based interface			X		X
Wearable	X	X		X	
Motion-based interface	X	X	X	X	
Augmented common instrument	X	X	X		

Token+Constraints

Ullmer et al. give a very exhaustive description of the token+constraint tangible interface type: *"tokens are discrete, spatially reconfigurable physical objects that typically represent digital information. Constraints are confining regions within which tokens can be placed"* [51]. In this architecture, the physical tokens can be manipulated and associated within the spatial or mechanical constraints of the system. The LogJam [5] system is an example of such architecture.

Pressure-Based Interfaces

Pressure-based interfaces are systems that responds to a physical force applied on them or on their components. Pressure-based interfaces can be mechanical switches, like the common and simple push-buttons. They can also be reactive to impact or sense the amount of pressure applied on them. Examples are MIDI piano-like keyboards, pads and haptic sensors surfaces [9, 26, 40]. The Polymetros [4] system is another example.

Wearables

Wearable systems are in continuous physical contact with the user's body, unlike others forms of interfaces [38]. They can be used to track the user's movement, like for example in the VJacket project [53], where sensors were integrated into clothing and the dancing movement of the user were used to interact with video projections. In the WaveForm system [2] , the glasses and gloves worn by the user are used by the system to track the position and the movement of the user. The in-air gestures of the user are used to control video animations on a distant display.

Motion-Based Interfaces

Motion-based systems react to the physical displacement, acceleration or movement of the interface. For example, the maracas-like Rhythmism systems [20] need to be shaken or turned to modify the visual effects on a video. The uPoi [45] generates different visual and sounds according to the acceleration of the instrument when swung around the body of the performer. The Ashitaka [29] instrument reacts to its interface being stretched, twisted and moved around.

Augmented Common Instruments

This last type of interface is similar to Ishii description of "Augmented Everyday Objects" [19] but is adapted to the domain of Digital Live Arts . Augmented Common instruments take the shape and features of pre-existing artistic objects but are digitally augmented. Examples are the MIDI keyboards and electronic wind instruments [1, 39, 47].

Interface types and DLAA design intentions

Table 2 highlights the prevalent implementation types usage for the realisation of the different DLAA design intentions. For example, the collaborative aspect of interactive surfaces has already been demonstrated several times [44, 48]. Also, wearable and motion-based interfaces may provide more visibility to the interaction and therefore enhance performativity. Interfaces requiring precises motions and constant attention such as constructive assembly and Token + constrains can allow for more engagement. Table 2 is to be used as a guide and taken with a pinch of salt since many different factor other than implementation types can contribute to the fulfillment of the design intentions. Other interface characteristics to consider, such as complexity and affordance, have been previously discussed in the design intentions section.

NUAGE Prototype

To put the DLAA methodology into action, we developed NUAGE, a tangible interface that controls audio and video content in a live, real-time and performative context.

Figure 3: Picture of the NUAGE interface prototype and it during audiovisual tests

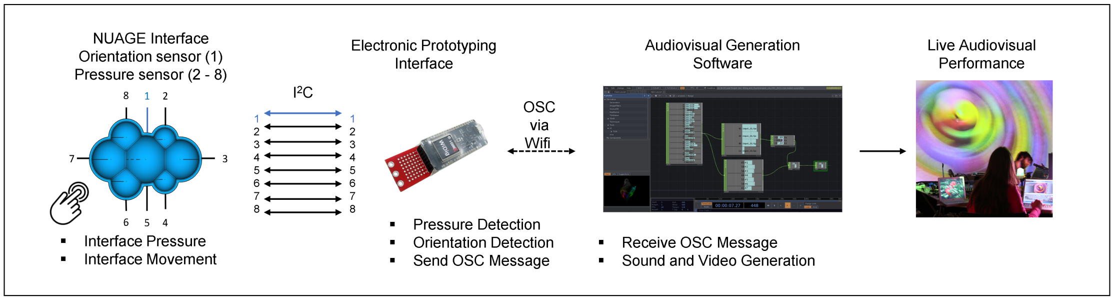

Figure 4: Fonctional diagram of NUAGE prototype interface

We aimed at developing an accessible interaction device for both audiovisual artists and their audience. The DLAA approach provided a structured understanding of the peculiar design requirements of such AV performative instruments.

DLAA's design intentions guided the NUAGE implementation choices of appearance and functionality.

The proposed prototype, pictured in Figure 3, is a mix of the pressure-base and motion-based type of interface described in the previous section of this paper. It takes the shape of a squeezable cloud that can be hold in the hands of the user and freely moved around. Pressing on the different parts of the cloud and moving it around controls various audio and video effects.

The quirky and colourful appearance of the NUAGE makes it visually attractive and intriguing for both the audience and the user. This, as explained before, enhances performativity, engagement and meets the aesthetics design intention.

The intuitive usability of the interface leads to a greater engagement of the user. Indeed, pressing the interface is an intuitive action due to the softness of the material it is made of. The expressiveness and participation design intention are achieved due, among other things, to the possibility of moving the NUAGE around.

Therefore, the combination of the pressure and motion types of interfaces in addition to its visual and physical aspects allows NUAGE to meet all of the presented DLAA design intentions for audiovisual instruments.

System Architecture

NUAGE is a 3D silicone structure composed of seven adjacent hollow spheres or bubbles. Each of these independent hollow bubbles are equipped with a barometric air pressure sensor inside. An orientation sensor is also placed in the center of the interface. The sensors are connected to a microcontroller that sends the output values to a computer via WiFi and the Open Sound Control (OSC) communication protocol.

An external audiovisual content creation software, for example TouchDesigner or Max/MSP, can then receive the sensor values and generate different video and sound effects. This process is illustrated in figure 4.

Squeezing a bubble changes the air pressure inside of it. Therefore, this action could, for example, make the colour of an image change. Moving the interface and turning it around changes the output orientation values, this could perhaps change the rhythm of a music piece.

Creation of the prototype

In order to make the interface squeezable, the physical structure of the prototype is made out of silicone. To obtain the desired shape, a mold assembly in which the silicone was poured was developed.

The mold assembly is composed of two pieces, a base and a top cover. It is 3D printed. Pouring liquid silicone into the base, then closing the assembly with the top cover creates a half hollow section of the NUAGE. The NUAGE prototype is made of two sections of cast silicone. The sensors are inserted inside each bubble as shown in figure 5. The two sections are then glued together to create hollow bubbles.

The hardware implementation of the prototype was done with the I-CubeX line of products [17]. The electronic prototyping platform used is the WiDig [16]. It has 8 sensors inputs and it sends and receives OSC message via WiFi. The orientation sensor placed at the center of the interface is an Orient4D sensor [15]. It is connected to the fisrt input of the WiDig. The air pressure sensors placend inside each of the seven bubles are connected to the inputs two to eight of the WiDig. They are Air2D sensors [14].

NUAGE in action

The NUAGE prototype was used to create a live AV performance that will be presented at the Montreal Société des Arts Technologiques. The interface controls the audio synthetic generation and video projection on the immersive dome of 18-meter. The artist, at the center of the room, will only use the NUAGE, squeezing it and moving it around, to create a 360 immersive experience for the audience. Video capture of the event will be available here: https://bit.ly/3jq5Eei. This

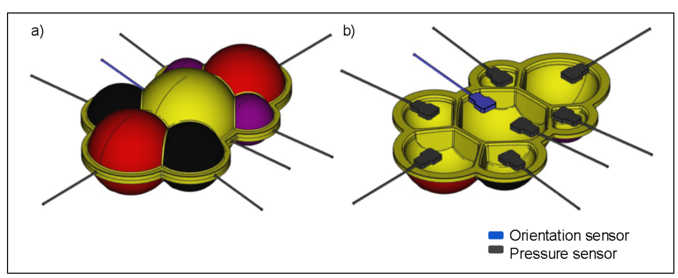

Figure 5: Technical drawing of a perspective (a) and sectional (b) view of the interface and sensor assembly

performance will be a great moment for an in-the-field evaluation of the prototype.

Conclusion

This article presented DLAA, a novel approach to the design of performative AV instruments based on Tangible Interaction principles. We have seen how the key concepts of Tangible Interaction are applied in a distinctive way by DLAA. In order to map this approach, we detailed its peculiar design aspirations, characterised its interface types. We also presented the NUAGE prototype that implemented the DLAA methodology. This paper emphasized that the interaction with an interface should not only be studied from the point of view of the direct user but should also be studied more broadly if other people are involved in the interaction. Few researches consider the audience reaction to a performer using a tangible system, which takes a strong role in our DLAA approach. Future work should focus on investigating the audience understanding and perception of the performers' actions.

In conclusion, DLAA gives a better comprehension and perspective on how both the artists and the public interact and appreciate AV Tangible Interaction systems. It also structures, guides and systematizes the design process of such instruments. It provides designers with an alternative design approach that can be used in many different and artistic fields.

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