Designing a Musical Instrument: Enlivening Theory Through Practice-Based Research

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Introduction

The Arcontinuo is an electronic musical instrument that was conceived with the intention of overcoming the difficulties of other instruments that have failed in getting a consistent place in the musical scene. Its creation was based on a model founded in concepts of interaction design research and narrative identity that we intend to describe in detail in the first part of this article. This model, we hope, could be applied to any design research process providing an approach to creating products, services and experiences with a quality rooted in the personal and collective organization of meaning. The second part of the article explains the implementation of the model as a case study, the Arcontinuo.

Where Is Quality to Be Found?

This question, which we take from Robert Pirsig's novel, *Zen & the Art of Motorcycle Maintenance* (1974), is formulated by Phaedrus, the main character, who muses on the subtle dilemma it poses to the inquisitive mind. Determined to arrive at a competent understanding of quality beyond its strictly physical aspects, Phaedrus's line of reasoning leads him directly to what we might call the phenomenology of quality. Does quality reside in the object's properties or in the subject's mind? If quality were an inherent property of the object, then there should be an instrument capable of measuring it. But beyond its functional features, the emotional and symbolic aspects of an object remain elusive. One might argue that quality resides in the subject's mind, which is equivalent to saying that quality could be just about anything you wish. But if that were the case, quality would become entirely subsumed by subjectivity. However, closer observation into the matter radically contradicts such a presumption.

Phaedrus argues that quality cannot be independently related with either the subject or the object and polemically states that it can only be found in the relationship between the two: *"It is the point at which subject and object meet."*

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This finding is decisive, for it suggests to him the idea that *"Quality is not a thing. It is an event."*[1] Quality is the event at which the subject becomes aware of the object.

"And because without objects there can be no subject—because the objects create the subject's awareness of himself—Quality is the event at which awareness of both subjects and objects are made possible."

Pirsig closes his argument with a statement that gives the impression of an impoverishment in the quality of the designed environment: products, services, and spaces that induce a poor interactive engagement.

"Quality is not just the result of a collision between subject and object. The very existence of subject and object themselves is deduced from the Quality event. The Quality event is the cause of the subjects and objects, which are mistakenly presumed to be the cause of Quality."

The Quality of Interaction

The interaction event—or process of interaction—between two entities of whatever kind is a basic phenomenon of the natural world that has been the subject of study by cognitive sciences, such as psychology, sociology, and anthropology, among others. Let us take up Francisco Varela's concept of interaction, which he introduces in his work on the biology of cognition. Varela defines interaction as a double coupling process in which an organism draws meanings from its environment. Mutual modification means that the outer world, arguably objective in itself, can never appear fully objective and stable to the observer because what the observer perceives is constantly being interpreted and reinterpreted and, thereby, modified. The common tendency is to associate "communication" and "information" with a purely "receptive" audience. But messages are always modified in some way by the interaction with the receptor's point of view. In fact, human organisms are closed to information but open to interaction as a way of securing their essential autonomy.[2] Varela makes a distinction between the general environment and the organism's specific world, in which the latter interacts. This body-in-space clearly functions as a body-on-space, through its interactions with the environment. However, the coupling is only possible if these encounters are experienced from the organism's own perspective. At the same time, the organism cannot live without the regularity or periodicity of this constant coupling. If this coupling or associative activity were to cease, the organism would disappear.[3] Thus, interaction is a critical event in the quality of each and every form of life.

1 Robert Pirsig, *Zen & the Art of Motorcycle Maintenance* (New York: William Morrow and Co., 1974), 215.

2 Francisco Varela, *El Fenómeno de la Vida* (Santiago: Dolmen Ediciones, 2000), 140-50.

3 Ibid., 67-68.

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The Codetermination of Interaction and Identity

Interaction is not a self-contained fact. Quite to the contrary, it happens within a context, and it is determined by the intention of a particular identity. As Varela suggests, a correlation seems to exist between the kind of interaction and the specific identity of the subject who interacts.

Varela makes his argument for the living organism's *autonomy* as a basic condition in understanding the process involved in its constitution by establishing two key propositions. The first proposition defines an organism as the *process* of constituting an identity. An identity is a unitary coherence that is not structurally static but instead is itself a structuring process. The second proposition states that the emergent organism's identity provides it with a reference point from which to operate within a specific domain of interaction. Thus, identity and interaction codetermine each other as two sides of the same coin: the organism's *self-organization*.[4] In other words, in the case of human organisms, the subject interacts as a particular identity with a particular aspect of the objective world, and at the same time the subject's interactions with that aspect of the objective world build up his or her own identity. In the animal world, this phenomenon, defined by Varela as "cognitive identity," determines the efficacy of self-organization—in itself indispensable to survival—within a specific environment. Actuator and receptor organs linked by a neuronal net enable the development of actions that require efficacy, such as hunting, killing, migrating, mating, and so forth. However, this efficacy is not achieved instantaneously. A long, drawn-out process of recursive interactions, in which trial and error repetitions build up a strong neuronal path, eventually allows the animal to acquire the skill or dexterity it needs to increase efficacy. Human beings share this cognitive efficacy with animals but with a special difference: They use abstract language. Human language allows for the exchange of personal experiences. This ability to transfer knowledge to others by means of narrative and then to formulate strategies coordinated by language is an evolutionary resource that helped to save the species, rather poorly equipped in physical attributes compared to most animals, particularly to our predators.

Narrative Identity

Basing a substantial part of their epistemology of cognitive identity on the findings of biologists Varela and Maturana, post-rationalist psychologists Vittorio Guidano and Giampiero Arciero explain human or personal identity as narrative identity.[5] Echoing Varela's proposition that identity and interaction codetermine each other, Guidano[6] sets personal identity within a reality that is a multi-dimensional process articulated by different levels of interaction. From this interactive process, knowledge emerges as a

4 Ibid., 51-52.

5 Giampiero Arciero and Vitorio Guidano, "Experience, Explanation, and the Quest for Coherence," in *Constructions of Disorder,* Robert Niemeyer and Jonathan Raskin, ed. (Washington, DC: American Psychological Association, 2000), 91-118.

6 Vitorio Guidano, *The Self In Process: Toward a Post-Rationalist Cognitive Therapy* (New York: The Guilford Press, 1991).

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self-referential (autonomous) continuous ordering of the emotional perturbations experienced in the subject's praxis—a perspective that echoes in turn Maturana's ideas: On the one hand, *"Every emotion constitutes knowledge,"* and on the other hand, the subject's source of knowledge is his or her own personal history of interactions, what I call *the ordering.*[7]

Guidano explains this multi-dimensional process by way of a conceptual model he introduced in 1991: *The Self System*.[8] Starting from Maturana's ideas that "All the things we do, we do them from an emotion," and "Every doing is knowing,[9] Guidano argues that the emotional experience is essential for knowledge by understanding human knowledge as the tacit, proactive, and emotional process whereby meaning is attributed to the immediate emotional experience.[10] Our *self* then organizes personal meaning—personal because the emotions we experience are meaningful—at two levels: first, at a tacit level, related to the quality of those emotions and second, at a narrative level, where we explain these emotions we have experienced. Why do we need to organize emotions in the form of a narrative or an explanation? The reason has to do with the need for perceiving ourselves and our environment as a familiar and stable world.[11] For Guidano, human existence is, among other things, a constant emotional torrent, and the need for a narrative is essentially the need for organizing the self when facing that torrent. Narrative allows us to distance ourselves from our immediate experiences by means of self-referential symbols (both non-verbal and verbal) that represent these experiences, conferring to them a certain degree of coherence with a view to self-organization. Thus, the relation between immediate experience and explanation corresponds to the relation between experienced meaning and narrated meaning.

Also, the need for narration is inscribed in our human condition as intersubjective beings. The explanation of meaning is a defining act of the *social self,* which needs to exchange experiences with others who, for their part, act as a *knowledge mirror,* and to coordinate actions with others to ensure the survival of the group. The self system proposed by Guidano defines identity as the systemic process that arises from the relation between experimented emotions (immediate experience) and the explanations of these emotions. Tacit and explicit knowledge translate what is *exceptional* into what is conventional. The self-system operates by means of two different types of sensibility that William James described during the early years of modern psychology:[12] the sensibility for the conventional, familiar, everyday experiences defined as *sameness,* and the sensibility for the exceptional, diverse, and new, defined as *selfhood.* Sameness is perceived as an emotive sense of continuity of oneself in reference to one's personal history. Selfhood, or ipseity, is perceived as "the constancy of oneself" or

7 Humberto Maturana, "Lenguaje y Realidad: El Origen de lo Humano," *["Language and Reality: The Origin of the Human"]* in *Desde la Biología a la Psicología, [From Biology to Psychology]* Jorge Luzoro, ed. (Santiago: Universitaria, 1989).

8 Guidano, *The Self in Process.*

9 Maturana, "Lenguaje y Realidad," 99.

10 Michael Mahoney, "Psicoterapia y Procesos de Cambio Humano," in *Cognición y Psicoterapia,* Michael Mahoney and Arthur Freeman, ed. (Barcelona: Paidós, 1998) and Michael Mahoney, *Human Change Processes* (New York: Basic Books, 1991).

11 Vitorio Guidano, *El modelo cognitivo posracionalista. Hacia una reconceptualización teórica y clínica.* (Bilbao: Desclée de Brouwer, 2001), 123.

12 Giampiero Arciero. *Estudios y Diálogos Sobre la Identidad Personal* (Buenos Aires: Amorrortu, 2005), 184.

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the multiplicity of a "who," moment by moment. Our consciousness of our personal history seeks to accommodate the natural tension between sameness and selfhood by recourse to a narrative plot with temporal characteristics, wherein language is used to integrate emotion and explanation into the creation of an explicit identity. This is what Guidano calls narrative identity.

Which brings us to the question at hand: In what way can these notions of human identity and of the self-system be useful for the design research process?

Design Research Process, Interaction, and Narrative Identity

We see in Pirsig's assertion that "Quality is not a thing. It is an event"—a call to designers to be more aware of the quality of the subject-object interaction in designing a product, service, or experience. Laurel, Shedroff, and Ireland,[13] among many other experts writing on design research, have been reflecting since the beginning of this century on how to expand the designer's self-referential scope—that is, on how to integrate the pure physical design, or the form-style problem, what Shedroff calls "sensory design,"[14] with the building of meaning and social value. From this perspective, the understanding of people and culture is these days considered to be essential for the enhancement of design research.

User-oriented or person-oriented design seems to be the major trend in this field. This design methodology arose first in the field of human-computer interaction (HCI), which centers its approaches and techniques on whether intended users can perform their task objectives easily and efficiently. Shedroff later expands on this methodology by arguing for interfaces and designs to simply be usable is not enough: "They also must be desirable, useful, needed, and understandable." Because they are themselves human cultural products, there ought to be an immense variety of them.[15] Norman contributes to this trend by adding such human dimensions as visceral, behavioral, and reflexive aspects, which emerge in the interaction with a product.[16] The tendency, then, is to design for the subject—and even more than that, to design *with* the subject, as participatory design proposes.[17]

Is the design research process now merely a survey about the subject's needs and expectations? The focus ought to be right on the subject-object encounter, which is where the quality designed is supposed to be found. Thus, we argue for the need to focus on the process itself. The process of constituting an identity that emerges from interaction encompasses the entire quality event, including the specific context in which it happens (the personal and social world).

At this point, we propose to use the *self-system* process approach to make sure that our design research process has an appropriate epistemological starting point. Our design research

13 Brenda Laurel, ed., *Design Research, Methods, and Perspectives* (Cambridge: The MIT Press, 2003), 17-19.

14 Steven Diller, Nathan Shedroff, and Darrel Rhea, *Making Meaning* (San Francisco: New Riders Publishing, 2005), 155.

15 Ibid., 155.

16 Don Norman, *Emotional Design: Why We Love (or Hate) Everyday Things* (New York: Basic Books, 2004), 148.

17 Brenda Laurel, "Design Improvisation," in *Design Research, Methods and Perspectives,* 49.

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process is not a literal application of the self-system process but is simply an extrapolation from post-rationalist psychology to design. We can observe, in the interaction event, the relationship between experimented emotions (immediate experience) and their verbal and non-verbal narratives in the form of tacit and explicit knowledge, where what is exceptional is translated into what is conventional. In other words, it becomes possible to observe and to register some clues as to how a narrative identity interacts within its world. After establishing a "who" (an identity) and its context, the following steps need to be taken:

1. Gather emotions and their relation to verbal narratives (tacit and explicit knowledge) in the form of explanations, reflections, thoughts, considerations, ideas, and so on. Also gather non-verbal narratives (tacit knowledge) in the semiotic form of artistic expressions, such as music, dance, drawings, and the like.
2. Create two simultaneous scenarios for the gathering process: sameness or the sensibility for the conventional, and selfhood or the sensibility for the exceptional.
3. Establish an exhaustive, pertinent set of key interactions that serves as a reservoir for problems and opportunities for designing, such as needs and expectations captured in the sameness scenario, and gestures and behaviors observed in the selfhood inquiry.

The data to be gathered consists of a collection of personal meanings, at which we arrive by noting how the subjects explain their emotions and non-verbal narratives (i.e., their tacit knowledge), so that in the process of the explanation, the data become explicit knowledge. Thus, after the data processing is completed (e.g., using taxonomies, hierarchical diagrams, statistics, etc.), we should know more about how our subjects organize meaning. The analysis undertaken can be both qualitative and quantitative over a small group of people (8 to 12) because establishing archetypes is advisable to get a deeper insight into the personal meanings of each subject.[18]

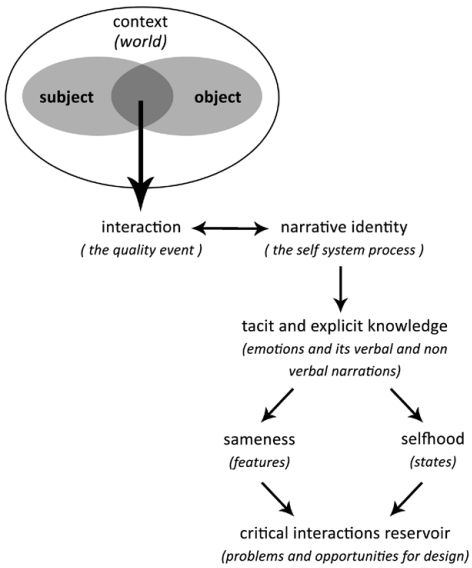
Placing the gathering into two different experience dimensions or "sensibilities" as Guidano names them, is important. One of the scenarios consists in capturing the sameness experience dimension. Sameness is a synchronic image of meaning, analogous to a "photograph" that shows a collection of steady features (emotions, explanations, and non-verbal attributes). An important instrument in this experience dimension is the interview in any form—whether focus group, one-on-one, or dyad.[19] Other ways of capturing sameness include looking at what people write in social networks, listening to what they say in meetings of any kind, or studying the variety of images and sounds they produce.

18 Jeffrey Rubin, Dana Chisnell, and Jared Spool, *Handbook of Usability Testing* (Cambridge: The MIT Press, 2008), 114.

19 Christopher Ireland, "Qualitative Methods: From Boring to Brilliant," in *Design Research, Methods and Perspectives*, 23-29.

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Figure 1
Diagram of the design research model based on the narrative identity process.



However, this model cannot be used independently because it will always be contrasted with the selfhood findings or "the constancy of oneself," the multiplicity of a "who," *moment by moment.* It is the sensibility for the unexpected, the contingent, the new. It is a diachronic image of meaning analogous to a "movie" that exposes different emotional and narrative states, such as functional-behavioral issues, body language, special displacements, movement, the acts of liking or disliking, and many others. An important instrument for the selfhood capture is ethnography.[20] Ethnography and participatory observation have the special virtues of locating the observer inside the "movie" and of providing a richer narrative structure by registering parameters such as rhythm, intensity, order of episodes, plot, and the like. Another important instrument is *informance*,[21] which consists in building a determined performance to obtain information.

The results obtained from gathering with both the sameness and selfhood interactive processes should be compared. In some situations, the coherence between features and states is subtle. For example, in some cases, the preferences—made manifest in what a person says and in what that person actually does—*cannot* be exactly the same. Such a finding can be interesting when it brings to light tacit or explicit aspirations, desires, misconceptions, and so on. A more discriminating interpretation of incoherence might lead to very creative and appropriate solutions that might enhance the quality of the interaction event.

The great benefit of gathering data in the sameness and selfhood interactive process is the rich reference domain of the *critical interactions reservoir* obtained from the research results, encompassing both negative and positive issues (problems and opportunities), as well as every tacit or explicit feature or state. We summarize these ideas by way of a diagram (see Figure 1). The

20 Ibid.

21 Laurel, "Design Improvisation," 51.

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place where the experience of quality happens is in the interaction event between subject and object within a specific context. Because interaction is not an isolated phenomenon, but a process of double coupling with identity, the correlation between interaction and identity is incorporated in the narrative identity process. This process is what generates tacit and explicit knowledge. As tacit knowledge in the form of emotions is translated into verbal and non-verbal narratives, it becomes explicit knowledge. Thus, we argue for the need to observe narrative identity within two different experience dimensions or sensibilities: (1) sameness, or the synchronic display of features ("the photograph"); and (2) selfhood, or the diachronic display of states ("the movie"), encompassing what is conventional and familiar with what is exceptional and contingent. When the data gathered from these dimensions is processed and compared, the design research process proves to be suitable because it is rooted in the rich reference domain provided by the critical interactions reservoir. Applying the model in Figure 1 as a methodological strategy for design research allows design projects to be based on problems and opportunities much more deeply rooted in the actual quality event—a dramatic improvement over conventional models centering exclusively on the physical design or on the form-style problem.

The Arcontinuo: A Practical Application of Innovation in Electronic Musical Instruments

As a practical application of our design theory, we present the Arcontinuo,[22] an electronic musical instrument we have been working on since 2009. The creation of musical instruments is, for a variety of reasons, probably one of the most demanding challenges in design. As Robert Moog states in the foreword to Pinch's and Trocco's book,[23] "Musical Instrument Design is one of the most sophisticated and specialized technologies that we humans have developed […] [W]hen we speak of musical instruments today, we understand that we are talking about precisely made and finely tuned objects."[24]

Moog emphasizes that "music-making requires both the musician and the listener to function at the very limits of their perceptive and cognitive capabilities. Therefore, a musical instrument has to be as effective as possible in translating the musician's gestures into the sonic contours that he [sic] is envisioning." When musicians perform, says Moog, they feel their instrument responds as they hear the sounds that it produces.[25]

In traditional musical instrument performance, the relationship between the musician and the instrument is a highly developed one. Long years of daily practice are needed to acquire an intimate and thoroughgoing knowledge of the instrument in all its physical and mechanical attributes and to become proficient at it before the musician can be said to have actually mastered the

22 Claudio Bertin et al., "The Arcontinuo: A Performer-Centered Electronic Musical Instrument," in *Proceedings of the International Computer Music Conference* (San Francisco: International Computer Music Association, 2010), 80-87.

23 Trevor Pinch and Frank Trocco, *Analog Days* (Cambridge: Harvard University Press, 2004).

24 Ibid, v.

25 Ibid, vi.

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instrument. Seen in this light, the relationship between a musician and the instrument is much more complex than we might expect from the typical interaction between a human being and a machine. An obvious reason is that our relationship with a musical instrument is based on the time we spend living with it.[26]

When inventing acoustical instruments, designers have to find the optimal compromise between the abilities of the human body and the physical constraints involved in sound production. The gestures used in the act of playing an instrument depend to a large extent on the physics of the instrument.[27] Hence, the physical object and its acoustic properties are the medium between the performer's act of playing and the sound produced. By way of the instrument, the performer is able to affect all aspects of the music, from the micro level of timbre to the event level of note articulation, to the macro level that reflects compositional structure.[28]

The case of electronic instruments is somewhat different because sounds can be generated without any physical constraints, and the designers are free to choose whatever gestures they prefer and to make them link up with the sounds produced in whatever way they want.[29] Electronic musical instruments have made possible the dissociation of the control surface (e.g., keys, sliders, valves, etc.) from the sound-generating device (e.g., speakers).[30]

For many years, the keyboard and its accompanying set of knobs were the standard interface devices used in the making of electronic music. But a large body of experimental work now connects HCI theory with music performance.[31] The wide variety of sensors available has made possible the translation of virtually any real-world physical gesture into electrical energy, so that they serve in fact as a control signal for an electronic sound source.[32]

Creating a performer/instrument dynamic is a worthy goal in electronic instrument design. It entails the creation of the material conditions that allow performers to attain such a level of technical command and such depth of intuition in their interaction with the instrument that they no longer need to be consciously aware of the technicalities of its manipulation. How to achieve this intuitive musical fluency with a technology-based instrument becomes an artistic challenge.[33]

The Design Research Process

As we have suggested, the governing idea behind design research consists in capturing meaning from personal identities to identify and understand the relevant interactive behaviors, and then to progressively give shape to a physical object that incorporates these behaviors in the intentionality of its design. This process can be imagined as a spiral, with alternating cyclical stages of testing and redesigning based on a specific population of potential users. Through the sameness and selfhood experiences previously

26 Atau Tanaka, "Musical Performance Practice on Sensor-Based Instruments," in *Trends in Gestural Control of Music,* Marcelo Wanderley and Marc Battier, eds. (Paris: IRCAM, 2000), 389-406.

27 Daniel Arfib, Jean-Michel Couturier, and Loïc Kessous, "Expressiveness and Digital Musical Instrument Design," *Journal of New Music Research* 34, no. 1 (2005): 126.

28 Tanaka, "Musical Performance Practice on Sensor-Based Instruments," 390.

29 Arfib et al., "Expressiveness and Digital Musical Instrument Design," 126.

30 Axel Mulder, "Towards a Choice of Gestural Constraints for Instrumental Performers," in *Trends in Gestural Control of Music,* Marcelo Wanderley and Marc Battier, eds. (Paris: IRCAM, 2000), 32.

31 Sile O'Modhrain, "A Framework for the Evaluation of Digital Musical Instruments," *Computer Music Journal* 35, no. 1 (2011): 28-42.

32 Bert Bongers, "Physical Interfaces in the Electronic Arts: Interaction Theory and Interfacing Techniques for Real-Time Performance" in *Trends in Gestural Control of Music,* 42.

33 Tanaka, "Musical Performance Practice on Sensor-Based Instruments," 399.

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described, the findings are synthesized as key interactions that eventually serve as the source of new problems and opportunities for the design process.

Stage 1: Sameness Capture

The essential goal of this stage is to capture the narrative elements of what people say about a given topic. The procedure consists in conducting personal interviews, which can be done in a variety of formats. We chose an axial and open conversation technique: axial, because instead of relying on a survey of objective questions, a discussion of topics derived from our research goals was proposed; and open, because any spontaneous deviation from the topic of conversation was considered potentially meaningful. Our subjects were 17 musicians representing a wide range of social and professional backgrounds and interests, some of which included performance on electronic and acoustic instruments. The subjects had different degrees of musical proficiency, and their ages ranged from 22 to 58.

The topics proposed were the following:

- Instrument manipulation
- Control over timbre, pitch, and rhythm
- Cognition and learning
- Performing on stage
- Electronic instruments
- Acoustic instruments

The session was recorded on video and analyzed afterward.

The main goal of the sameness stage is to elaborate a narrative summary. To that end, the needs and expectations were sorted by topic and evaluated both quantitatively and qualitatively. Thus, the research methodology captures the symbolic and emotional aspects of what participants would expect from an electronic instrument. Key interactions become extremely valuable when used as triggers for the design process. In our case, the most relevant key interactions found were the following:

- *"I want the instrument to have continuous pitch."* The capacity to produce continuous pitch was highly desirable. The musicians argued that the limitations of discrete pitches, as evidenced for example, when playing a piano, was acceptable for mechanical devices, but that electronic instruments should allow for an unrestricted division in the pitch space. A recurrent narrative was that "I would like to rub my finger over a surface to get a continuous pitch." This objective instance of a strong interaction led us toward a technology closer to current touch-screens and farther away from the idea of keys, buttons, or any kind of discrete keyboard.

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- *"The instrument should allow for the use of human gestures."* Subjects were interested in ergonomic and haptic interfaces. The physical effort involved in playing an instrument for long periods of time becomes relevant when performers opt for a specific body posture or kinetic articulation.
- *"I would like to customize the interface."* Most potential users habitually interact with computers and would expect their instruments to have the same flexibility. They have developed skills to interact with interfaces, such as setting parameters, remapping, loading, and creating new sounds. They expect to find similar features in a musical instrument.
- *"I don't have time for a long learning process; it has to play easily." "Not everyone is meant to play instruments." "It should be challenging, difficult." "It should provide the opportunity to develop a skill."* The learning process was the topic that elicited the most divergent responses. Subjects who played electronic instruments were looking for a "plug and play" type of design solution, while subjects who played acoustic instruments were looking for an instrument that would require a more gradual development of skills and that would allow for the accuracy and sophistication of human control.
- *"I need a portable object that I can carry easily, like an acoustic guitar."* Carrying a big or heavy instrument was considered inconvenient. The human capacity to transport an instrument imposes constraints on its size and weight.
- *"The performance should be interesting to watch on stage."* Some electronic musical devices and interfaces are not visually appealing to the audience because the musician-instrument interaction does not appear to relate organically to the performance. Thus, taking into account the visual effect of the interaction between the musician and the instrument and, especially, allowing the audience to see what the hands are doing are important.

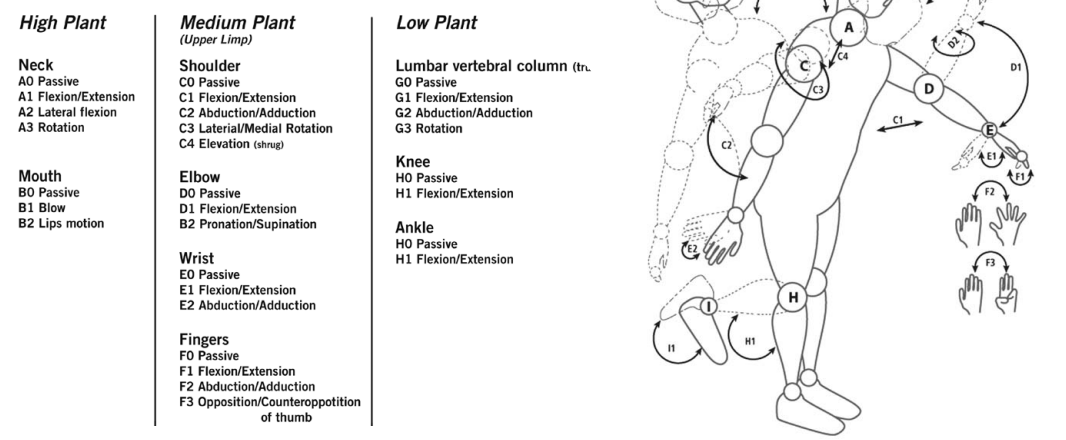
Stage 2: Selfhood Capture

As discussed previously, selfhood is the dimension of contingency—of the fact, the action. Although the observation of selfhood can take place in the context of a concert or rehearsal, in our case where the main goal consisted in capturing musical gestures, we designed a more controlled experience.

Based on the information gathered during the sameness stage, the subjects were made to listen to sets of recorded and synthesized sounds. They were asked to listen to every sound and

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Figure 2
Categorizing scheme for gestures, based in osteokinematic motions (the basic joint movements of the human body).



then, in a second hearing, to produce or suggest a gesture that, to their minds, would be required to generate that specific sound. Moreover, whenever the subjects imagined objects while listening to the sounds, they were asked to depict those images. The session was recorded on video, and all the gestures, comments, and drawings were quantified and analyzed. The result of this process yielded relevant information about gestures. A set of gestures based on osteokinematic motions[34] and incorporating most joint movements was used to categorize the gestures, as detailed in Figure 2. The upper limb gestures were the most recurrent in all sound categories, especially elbow flexion and extension, shoulder motions, and finger flexion and extension, as shown in Figure 3.

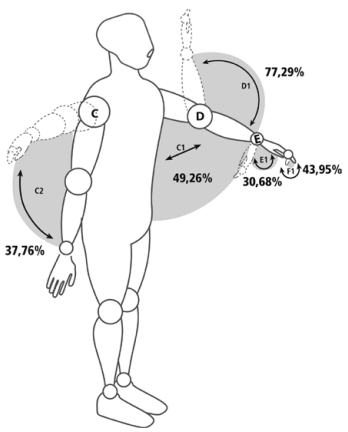


Figure 3
The five most recurrent basic gestures. Percentages were calculated by dividing the total count of each gesture by the total number of observed gestures.

Stage 3: Mockups

Based on the key interactions gathered in the sameness and selfhood stages, mockups were built and tested on subjects. The most recurrent gestures, objects, and interactions were used to shape three different mockups shown in Figures 4, 5 and 6.

Each mockup was assessed in terms of its functional, emotional, and symbolic traits. The mockup that received the highest assessment is shown in Figure 4. From a functional point of view, the elbow rotation seems to be a very natural gesture for music articulation. The percentage of recurrence (72%) is clearly indicative of an efficient gesture that mainly uses one articulation to displace the hand over a curved surface. Instrument size was similar to what musicians described in the sameness stage—that is, a size that allowed for easy and comfortable handling by the human body. Emotional issues, as well as the aesthetics of the shape, were highly valued. Symbolically, the benefit of capturing a natural ergonomic gesture, along with the hand position, up front facing the audience, was highly appreciated.

34 Donald Neumann, "Getting Started" in *Kinesiology of the Musculoskeletal System Foundations for Physical Rehabilitation*, Donald Neumann, ed. (Philadelphia: Mosby, 2002), 4-11.

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Figure 4
Mockup based on elbow rotation, finger extensions and a rigid surface to be finger rubbed.

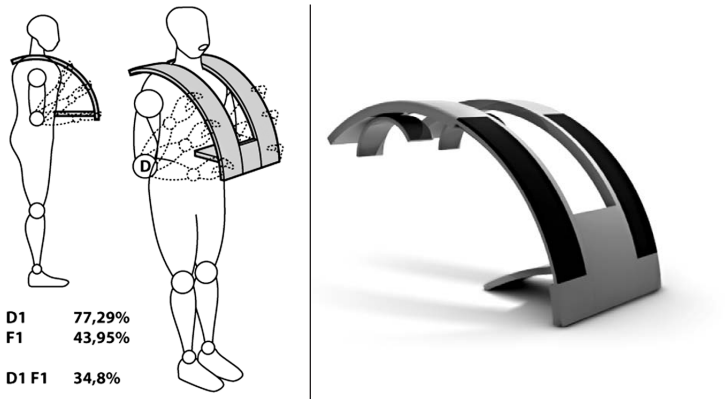


Figure 5
Mockup based on shoulder extension and abduction with a rigid conic surface to be rubbed by hand.

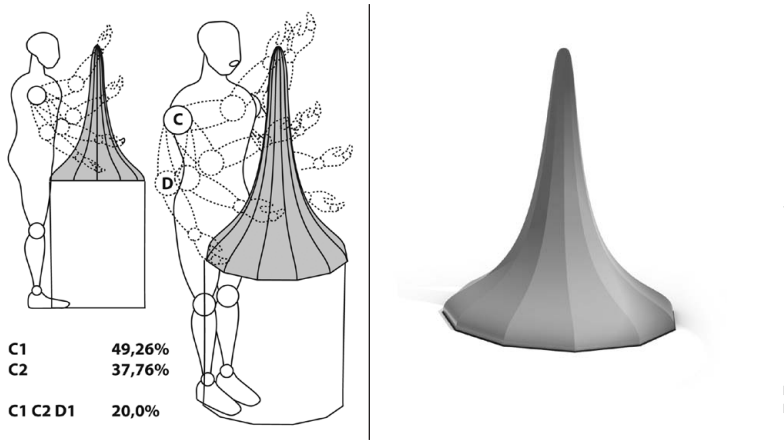
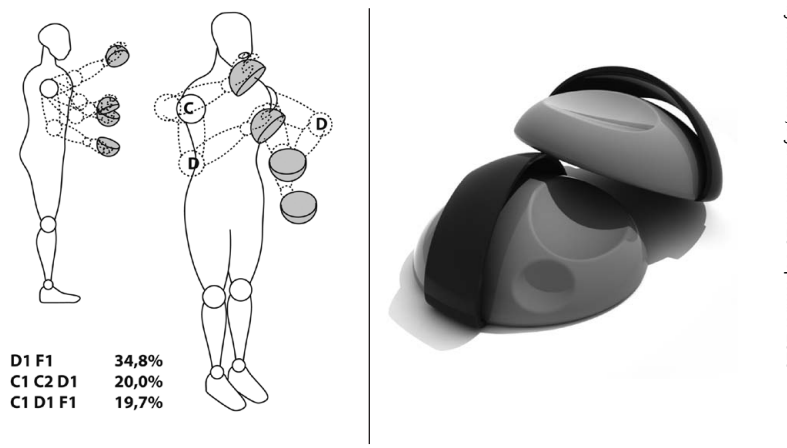


Figure 6
Mockup based on shoulder and elbow extensions with two semi spheres on the hands.



Stage 4: Functional Prototype

A more elaborate shape was designed for the construction of the playing surface, shown in Figure 7. The basic material used is wood, while the shoulder strap is made of aluminum. The instrument can be adjusted to fit different body shapes and sizes.

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Figure 7
Functional Prototype: The Arcontinuo.



Conclusion

The musical instrument created was strongly determined by the proposed design research model. For example, its continuous and curved shape, which, to our knowledge, no other electronic musical instrument possesses, was suggested from the data collected through the sameness and selfhood captures. We believe that one benefit of gathering data using our model is the possibility of obtaining a multidimensional set of critical interactions, encompassing both problems and opportunities, for designing useful objects in a great variety of domains.

By embracing an epistemological point of view centered on the quality of the interaction between the subject and the object, we have achieved a design research model that seeks out and finds key interactions relating to the personal identity of the exact consumer group for whom the product is destined. These interactions are captured by means of two experiential dimensions: sameness and selfhood. These two dimensions are addressed in an alternating cyclical—or spiraling—process in which the object is progressively adjusted to the expectations, feelings, needs, gestures, and opinions of that particular consumer group. Thus, the object designed is conceived and materially put together to reflect the user's meanings; it thereby receives the user's intellectual and emotional acquiescence, as most successful innovations ought to do. However, the designer's creativity and artistry in producing the form will always be decisive in the process of translating these meanings into a product.

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