Material embodiments of electroacoustic music: An experimental workshop study

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ABSTRACT

This paper reports on a workshop where participants produced physical mock-ups of musical interfaces directly after miming control of short electroacoustic music pieces. Our goal was understanding how people envision and materialize their own sound-producing gestures from spontaneous cognitive mappings. During the workshop, 50 participants from different creative backgrounds modeled more than 180 physical artifacts. Participants were filmed and interviewed for the later analysis of their different multimodal associations about music.

Our initial hypothesis was that most of the physical mock-ups would be similar to the sound-producing objects that participants would identify in the musical pieces. Although the majority of artifacts clearly showed correlated design trajectories, our results indicate that a relevant number of participants intuitively decided to engineer alternative solutions emphasizing their personal design preferences. Therefore, in this paper we present and discuss the workshop format, its results, and the possible applications for designing new musical interfaces.

Author Keywords

prototyping form, gestures, interface design

CCS Concepts

•Human-centered computing → User studies; Gestural input; •Applied computing → *Sound and music computing;*

1. INTRODUCTION

There exists a vast literature [2, 6, 12] on studies analyzing spontaneous rendering of sonic parameters to movement. The fundamental question of these studies has been elucidating what kind of gestures do listeners and performers associate with various musical sounds. Usually participants are asked to draw contours or move while they are listening to short excerpts of music. The intention is capturing instantaneous multimodal association of sounds or music. These results can be used to inspire intuitive interactions and musical controllers. Tanaka [15] asserts that the cognitive mappings enacted during these types of studies are always informed, mediated and inspired by the actual materiality of the controller used (i.e., size, material, shape, acoustic properties, etc.). However, we are not aware of previous studies focusing on the production of physical artifacts envisioned after following similar methods.

According to Clarke [4] we all have some ecological knowledge on how sound-producing actions relate to sound. The hypothesis that sound gestures identified in music reflect sound-producing gestures was shown by Henbing and Leman [8]. Godøy, Haga, and Jensenius [7] defined two types of sound-producing gestures. First, those human movements made with the intention of transferring energy to an instrument (*excitatory gestures*). Second, those human movements made with the intention of modifying the resonant features of the instrument (*modulatory gestures*).

There are also many previous studies analyzing how people move while they mime control of music. This gestural 'mimicry' [7] is what Godøy, Haga, and Jensenius described as performing 'air instruments' or making sound-producing gestures 'without making physical contact with any instrument'. Nymoen [12] also developed studies tracking people's hands while they played 'air instruments' showing that the most significant parameters mapped by participants are pitch, frequency centroid and dynamic. Caramiaux et al. [2] analyzed aspects of causal perception in sound. They tracked people's movements while listening to identifiable environmental sounds. Their results indicate that when the causing action is highly identifiable participants mainly mimed the sound-producing action. When no clear action could be associated to sound, participants traced contours related to sound acoustic features (e.g., pitch, volume, density, timbre, etc). These dynamic acoustic features are typically called the temporal morphology of a sound [14].

Interestingly, in many of these previous studies the physicality of the musical tools employed was deliberately diminished or given by default to participants. For this reason we decided to develop a new study on 'gestural mimicry' emphasizing the material aspects of spontaneous cognitive mappings.

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2. WORKSHOP STUDY GOAL

The goal of our workshop study was understanding how people envision and materialize their own sound-producing gestures into physical characteristics when designing musical interfaces. This information will inform the next steps of an artistic research project called 'Embodied Gestures' we are currently developing. Our plan is creating an ensemble of musical interfaces where each interface is specially designed to perform one particular sound gesture.

As we have explained, our workshop study departs from many previous studies describing how people mime musical control. As Caramiaux [3] has shown, musical cognition is always situated and sonic memories allude to certain objects to explain interaction. In sum, during the spontaneous rendering of movement people also envision artifacts. Therefore, at this workshop we proposed the production of mock-ups that, participants imagine, can perform the music they hear. Our intention was also obtaining a repertoire of artifacts and movements which could inform us about the most important physical features and actions we may include into our future designs.

We are not arguing here that the resulting mock-ups will be able to universally represent certain human movements. Each person will develop different cognitive mappings for envisioning form from sonic gesture. Instead, our intention was studying the whole series of mock-ups produced during the workshop for identifying possible design patterns and trajectories.

3. METHOD

3.1 Description and apparatus

The workshop study was prepared to have a duration of 90 minutes. Participants were divided into small groups of three to six persons. All sessions were video recorded. We informed participants in advance that they would be recorded and that they would have to mime actions. None of them rejected to take part of the workshop. All audio tracks were played back through quality full range loudspeakers.

Figure 1: Miming sound-producing gestures

The workshop study was divided into five phases iterated a number of times:

3.1.1 Introduction

At the beginning of every session participants were welcomed and introduced to the structure of the workshop. We took care of not describing any expected outcome. We also did not show examples of previous workshop sessions. Participants were asked to fill a questionnaire where they had to specify their cultural and musical background.

Figure 2: Artifacts produced by six participants

3.1.2 Verbal description of sound

In this phase our goal was obtaining verbal descriptions of the sonic contents used during this workshop-study. This information was used to compare aprioristic descriptions to the final produced mock-ups. In particular, participants were asked to describe each composition with their own words while they heard it. They answered separately using online questionnaires. In this phase participants only listened to sound pieces composed without transformations[1].

3.1.3 Miming sound-producing gesture

During this phase participants were asked to mime the action of a musical interface, they imagined, could perform the sound they hear. For assuring that participants would understand our goal, we also gave examples of what they should not do. For instance, they may not dance or trace the music but imagine they produce or control it. We also asked them to avoid miming that they play any existing acoustic instrument.

3.1.4 Production of mock-ups

Right after miming control of each composition, we asked participants to model mock-ups of the musical interfaces they imagined. The modeling material was clay. We explained participants that it was possible to create scaled versions. We did not limit the time to produce them.

3.1.5 Interview and mock-up explanation

During the last phase participants are asked to describe their mock-ups. First they may explain how their envisioned interfaces should be played, not only with their own words but also with gestures. Secondly, the material features of these interfaces (i.e., size, material). We did not reinforce any particular aspect of their answers (gestural actions, adjectives, or materials).

We iterated the last three phases (miming, modeling, and interview) a maximum of five times with different compositions. When participants needed too much time to model objects, they only iterated three or four times.

3.2 Audio contents: Electroacoustic music

A crucial aspect at this study was the preparation of adequate audio contents. These audios should be understood as probes making participants reflect and move. Therefore,

[1]As it is explained in Section 3.2, two versions of each composition were produced. In the first one, a sound gesture was played back a few times in a neutral way while in the second composition the same sound gesture was modulated using various musical transformations (i.e., pitch, density, etc.).

our sound contents had to incorporate aspects of the workshop goal. We agreed that one of the authors (Thomas Gorbach) would compose five short electroacoustic pieces. We resolved to emphasize three aspects in these compositions:

- The amount of sound-producing gestures in the composition. For example, a recording of a static sinusoidal signal does not contain evident sound-producing gestures. A recording of a violinist playing Paganini's Sonatas would be full of them.
- The amount of morphological transformations (changes in pitch, duration, density of sounds, etc.) existing in the audio track.
- The physical materials used to record the tracks.

Additionally, we had to add a few pragmatic constraints to the compositions. Firs, they would be one to two minutes long for limiting the overall duration of the workshop to 90 minutes; second, each composition would be composed using only one sonic content; and third, all morphological transformations had to evolve progressively to afford anticipation during mimicry.

Five short electroacoustic pieces were composed for the workshop study[2]:

- C1 is a threaded metallic bar being moved on a wooden table. It is transformed changing its volume and the speed of virtual tape effect. It is also controlled by a 3.5 Hz triangle low frequency oscillator.
- C2 is a recording of many small objects (metal, wood, and plastic) being mixed and dropped on a wooden table. It is transformed varying volume, pitch, and the density of objects.
- C3 was composed shaking a bunch of wrenches of different sizes. A constant reverb and a ring modulation centered around 70 Hz was also added. It was transformed varying the parameters of volume, pitch (12 tone scale), duration, and density.
- C4 was recorded rotating an old hand blender in front of a microphone. It was transformed varying volume, speed of a virtual tape effect, time delay, stereo panning, a band pass EQ, and a noise gate raising its volume linearly from start to end.
- C5 are hanging workshop wrenches being struck by a metallic bar. We transformed it reversing its attack and varying its pitch using a 12 tone scale. Using a digital tool we added a bending effect.

We prepared two versions for each of these five compositions. The first version is a composition in which sound material and sonic gesture are presented without any transformation. The second version incorporates morphological transformations of the original sonic material with the condition of keeping the original gestural character. The first version was used for the questionnaires while the second version was used during mimicry.

We decided that three of them would have a strong sound-producing character: C1, C2, and C4. In this case, listeners would easily envision particular materials or actions producing sound. Listening to the other two compositions (C3 and C5) participants would have much more difficulties in finding an archetypal material, object, or action causing sound. However, both C3 and C5 were composed with very different amount of sound transformations. These features allowed us comparing the results participants produced per composition.

Finally, it is also important to clarify why we decided to use electroacoustic music in our workshop study. First, we were not aware of any similar study using this type of composed music. Electroacoustic music makes use of both causal and non-causal sources but it also incorporates compositional structures (modulations, transitions, etc.). Undoubtedly, electroacoustic music has artistic intention, it is not mere sound. It has an aesthetic dimension. As we will explain later in this paper, miming control of electroacoustic music resulted very easy for all participants. It was an expressive exercise affording imaginative gestures.

3.3 The material used for prototyping: Clay

Two weeks before the first session, we organized a workshop demo with six participants. The goal was testing our method. At this session, we asked participants to produce mock-ups using a large range of materials (e.g., clay, Lego blocks, foam, cardboard, paper, tools, office materials, etc.). We soon noticed that these materials were biasing the outcomes. Participants adapted their envisioned instruments to the affordances found at those prototyping materials. For instance, they tried to play the compositions with scissors, tape rolls, pencils, etc. They soon forgot about the physical gestures envisioned in the previous phase. For this reason we decided to limit the material used in the workshop study. It had to be much more neutral. We agreed to use clay for molding artistic objects. It is cheap, friendly, and quite neutral, although it can also afford particular actions (e.g., breaking, smashing, rolling, etc.). Clay was also a difficult material to prototype objects like strings, springs, etc. However, only a few participants who envisioned quite complex instruments could not use clay. In these cases they drew their designs on paper.

4. ANALYSIS

4.1 Data collected

The workshop study was attended by 50 volunteers. They all were bachelor or master students of three different universities: 20 students of Informatics from Vienna University of Technology (TU Wien); 5 dance students and 7 computer music students from the Anton Bruckner University of Linz; 20 students from the Interface Culture media art department of the Art University of Linz. Their age ranged from 20 to 37 years except two persons aged 60 and 64.

The data collected consists in questionnaires about each participant's cultural background, verbal descriptions, written descriptions, recordings of participants mimicry, and video interviews explaining how their mock-ups should be played. After each workshop session, data were progressively tagged and archived. Examples of two phases of our workshop can be observed at Figures 1 and 2. In total they created 184 artifacts which were tagged, photographed, and archived. We filmed more than 30 hours of interviews and mimicry. We also archived 50 online questionnaires.

4.2 Methodology of analysis

The workshop study generated a tremendous amount of qualitative data which can be approached and analyzed from various research intentions. In the context of the *Embodied Gestures* project, the fundamental research questions guiding our analysis were *how do people envision musical interfaces when they mime performing electroacoustic music* and *whether it is possible to identify patterns of gestural*

[2]They are available for download from our website https://tamlab.ufg.at/blog/embodied-gestures-methodology/

affordances from these artifacts.

Apriori, we did not count with any founded theory to answer these questions. We decided to use the 'grounded theory' methodology [5] to infer an explanation from the artifacts produced. Understanding results through grounded theory means constant comparative analysis of data resulting in a progressive identification of categories of meaning. Its result is a theory about the phenomenon under investigation.

Our application of this methodology consisted in the comparative investigation of the artifacts produced. We printed photos of all the 181 artifacts. We first organized the photos in five groups, one per composition, resulting in groups of around 35 to 40 photos. All photos from the same group were put on a large table without any specific order. We did not assign any priory assumption about the categories we would discover through this analysis. There were no aprioristic categories or pre-established criteria.

Our grounded theory analysis was performed by three people. Two were involved in the data collection while the third person was at arms-length from the data in order to avoid bias. The potential for bias was accounted and the third person verified the others' categorizations.

During the analysis, we soon instinctively discovered artifacts with similar sound-producing gestures. We started clustering the photos. For each cluster we used a post-it labeling it, not using a description but defining an analytic property shared by all mock-ups in the cluster. After that we checked that the assumptions taken about the sound-producing gestures characterizing each mock-up were true. We iterated this process of categorization a number of times for refining it. During this process we documented all intermediate stages. Finally, we arrived at a point where we were not able to better classify the mock-ups. We observed how patterns of musical tools were intuitively identified by the type of sound-producing action. This repertoire of actions can be observed at Table 1.

5. RESULTS

5.1 How do people design musical interfaces with our method?

Our analysis shows that 87.5% of the mock-ups afford similar or highly compatible sound-producing gestures to the existing actions in the composition. The other 12.5% of participants created interfaces exploring alternative types of actions, non-related to the ones they had identified in the compositions. It is then clear that following our design method, the vast majority of participants prioritized sound-producing gestures. This is not surprising as each phase of the workshop emphasized this aspect.

From the analysis of the videos we observed that participants firstly envisioned excitatory gestures. The design of instrumental features enabling sound transformation was resolved at a second stage. Therefore, transformation was understood as an action modulating an already existing excitatory gesture. Certainly, this logic would allude to the causal schemes found in traditional musical instruments. We have also observed in which ways sound transformation was engineered by participants. Usually, they added an additional complementary affordance to its initial form or configuration (i.e., a new degree of freedom to the object) like knobs, sliders, buttons, additional sensors, acoustic effects, etc.

5.2 Design Patterns

The second research question deals with the possibility of identifying patterns of musical interface designs among the mock-ups produced. As we have previously explained, during the analysis we observed patterns of mock-ups with similar sound-producing actions. As we have explained, the complete repertoire of actions is described at Table 1. For instance, participants envisioned mostly two types of actions for composition C1. First, participants imagined interfaces which have to be touched in a linear or circular way with their fingers. Second, a relevant part of participants imagined they play interfaces which have to be scratched.

The existence of these design patterns reflect that our participants shared similar ideas about the main sound-producing action producing the sonic gesture.

This repertoire of actions, obtained in this case from only five sonic gestures among the many existing, will be extended with others along the duration of our project. In our opinion, this information can help other designers in our community about the particular actions people mostly identify with certain sonic gestures.

5.3 From verbal description to rendered movements and mock-ups

The analysis of verbal descriptions (phase 2) showed us that it is also possible to identify patterns of sound-producing actions among these descriptions. First, according to this analysis, different percentages of participants described the music using sound-producing actions. In particular, 48% of participants described C1 with a sound-producing action, 70% for C2, 22% for C3, 95% for C4 and 9.8% for C5. This information was complemented with descriptions about materials (i,e., a metallic object, a glass recipient), adjectives describing the overall experience (i.e., a repetitive sound, an alienating music) or metaphors alluding particular situations (i.e., music for meditating, a scary movie soundtrack). As expected, the less causal compositions (C3 and C5) were less described with actions but mostly with adjectives and material characteristics.

Interestingly, although it is possible to identify certain patterns among verbal descriptions, our analysis shows that many participants rendered very different gestures during verbal description and during mimicry. Thus, we infer that these mock-ups were ideated during mimicry. For instance, twelve participants described C1 as 'air resonating through a pipe'. However, finally only one participant of these twelve envisioned a compatible object. Similar cases are observable in the analysis of the other compositions. In our opinion, this fact indicates that mimicry was the main phase defining major characteristics about their imagined interfaces. This idea is supported by the analysis of the interviews. Participants usually alluded to the moment of miming for explaining why they took certain decisions regarding material features in their envisioned interfaces and musical tools.

6. DISCUSSION

6.1 Contributions

This experimental workshop study has revealed us a few possible contributions:

1. We consider this workshop as a novel ideation process for digital musical instruments. The structure of the workshop allowed us the rapid and efficient ideation of musical interfaces based on spontaneous cognitive mappings. Especially if the design intention is prioritizing sound-producing gestures. Including new ideation methodologies into innovation processes has been defended by Andersen [1] to engage participants with the crafting of new designs using creative methods.

Table 1: Repertoire of sound-producing actions with percentages per sound composition

Categories	Actions	C1	C2	C3	C4	C5
Malleable	Pressing	2,38%				
	Stretching	4,76%		2,77%	2,63%	
	Bending		2,77%		5,26%	46,87%
Playing with composed entitites	Rummaging		27,77%			
	Dropping objects		11,11%			
	Digging in		5,55%			
	Breaking		5,55%			
Touching with fingers	Linear	9,52%		5,55%		
	Circular	14,28%				
	Free	9,52%		2,77%		3,12%
Scratching with objects	One hand linear	19,04%				3,12%
	One hand circular	16,66%	19,44%	5,55%	52,63%	
	Between two hands		5,55%	2,77%	31,57%	
	Free	2,38%				
Mechanisms	Cranks and wheels	7,14%	5,55%		2,63%	
	Spinning	2,38%		2,77%		
	Air pipes	7,14%				
	Water stream		2,77%			
	Buttons					3,12%
	Sliders			2,77%		
	Colliding mechanisms		2,77%			
	Hinges				2,63%	
Moving one object	Balancing	2,38%	5,55%	13,88%	2,63%	
	Shaking		5,55%			
	Rotation around body	2,38%				
Drumming	Finger drumming			19,44%		9,37%
	Drumming with mallets			41,66%		34,37%

2. This workshop shows the benefits of integrating movement and having the body at the center of the design process. This allowed participants to approach interface design from a less language-oriented standpoint. The idea of designing with the body [9] or designing while moving has been put forward by professional designers and academics [10, 13] who practise bodily involvement in the design process of movement enabled interactions.

3. This workshop showed us how participants' designs can be studied and classified according to cognitive mappings. This embodied information can be useful to understand the phenomenological and aesthetic aspects of the experience of performing with particular instruments [11].

6.2 The role of materiality in this workshop

A pending aspect is the material aspects of participants' designs. All mock-ups were produced with clay. However, both at the introductory verbal descriptions and during the interview participants were asked to describe the materiality of each interface they imagined.

Verbal descriptions showed that a relevant number of participants associated what they listened with some specific material (C1–90%; C2–95%; C3–88%; C4–76%; C5–72%). The actual materials existing in the compositions were identified in different degrees (C1–69%; C2–46%; C3–72%; C4–85%; C5–94%).

From the interviews, we observed that the 69% of participants produced instruments envisioning only one material while the rest explained their artifacts could be made with various sorts of them. These materials were combined with others to afford acoustic or digital transformations (e.g., reverb or pitch shifting). Our perception is that although materials would be intimately connected to sound-producing gestures, participants understood it would not be practical to implement interfaces with certain materials (i.e. water or stone). Therefore, a metaphorical approach to these materials, in which a material is suggested but it is substituted with another -more practical or reliable-, would be a possibility for solving this design issue.

6.3 Variability in results according to the musical expertise or cultural backgrounds of the participants

The repertoire of sound-producing actions obtained with our method only describes the outcomes of our particular setup. From our analysis, we can assert that participants with different cultural backgrounds produced very different results. After analyzing the interviews, we can state that different identifications of sound-producing gestures have led to the diversification of the mock-ups produced. Depending on a participant's personal repertoire of bodily gestures and cultural backgrounds, the identification of sound-producing gestures was totally different. For instance, a carpenter would probably easily associate composition C4 to many typical actions produced at carpentry. In our case, many of our computer music students envisioned interfaces with complex technologies. many dancers imagined ample spaces to play with their bodies. Many computer music students envisioned variations of interface metaphors they already knew. This fact suggests the necessity of applying our ideation method taking into account an already existing cultural identification and context-related experience. In fact, iterating this workshop at other cultural or context-related backgrounds, even with different sonic contents, it would be possible to inspire many new and culturally specific types of musical interfaces.

Finally, it is important to explain that our participants also showed very different bodily skills: from professional dancers to people who usually never dance or do any sport. We even observed that the repertoire of gestures was very limited at some groups of participants (i.e., informatics students). However, they also found their own ways to mime during the workshop. This is a similar situation to the variability of cultural backgrounds. Designers and facilitators may develop their workshops and run their analysis taking into account the range of heterogeneity of their participants. For this reason, it is mandatory to include a personal information questionnaire in the structure of the workshop.

6.4 Verbal descriptions created false design expectations

We noticed that during verbal description, many participants (41%) asserted that a rusty door hinge was the sound-producing object for C4. Our expectation was that many variations of door hinges would be produced. However, this was false. Participants mostly envisioned other actions and objects during the workshop. In fact, only one person created a hinge-based controller. As we have previously explained, an identifiable sound source would not always be the main agent deciding the final physical instrument. From the analysis of results, we have observed that for this group of participants the bodily process of miming sound-producing gesture defined the envisioned instrument. These participants' initial spontaneous cognition process to identify sound-producing objects did not suggest an interesting action for performing music. Therefore, these participants imagined other compatible actions in the look for improving the experience of performing music.

7. FUTURE WORK

The results obtained during this workshop will inform an ongoing research project *Embodied Gestures* seeking to create ensembles of musical interfaces specially designed to perform particular sound materials and gestures. The idea is that each interface will have a form trying to afford an individual sound-producing gesture. Our intention is both composing and performing live electroacoustic music pieces with these ensembles of interfaces while we study how performers evaluate our designs.

8. CONCLUSIONS

In this paper, we have presented a method to study how people design musical tools inspired by their own sound-producing gestures. The method, based on a workshop, allowed us the rapid production of physical mockups representing musical interfaces. The results indicate that participants envisioned specific design patterns connected to sound-producing gesture. Therefore, from this workshop study we obtained a repertoire of actions that participants understood as interesting to perform particular sound gestures. Excitatory gestures and the physical materials of the interface were the central aspects defining design. In order to enable morphological transformations of sound (i.e. changes in pitch, dynamic and timbre), participants incorporated complementary affordances during the design process. In this paper we have also presented the repertoire of sound-producing gestures that participants have envisioned with our setup, inspired by five short electroacoustic compositions. In our opinion, the actions which are enacted following our method could inform musical interface designers, especially those prioritizing sound-producing gestures.

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10. REFERENCES

[1] K. Andersen. Making magic machines. *In 10th European Academy of Design Conference, 2012.*

[2] B. Caramiaux and P. Susini. Gestural embodiment of environmental sounds: an experimental study. *Proceedings of the International Conference on New Interfaces for Musical Expression, 30 May - 1 June 2011, Oslo, Norway.*

[3] P. Caramiaux, A. Altavilla, S. Pobiner, and A. Tanaka. Form follows sound: Designing interactions from sonic memories. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, Pages 3943-3952, Seoul, Republic of Korea, April 18 -23, 2015.*

[4] E. Clarke. Ways of listening: An ecological approach to the perception of musical meaning. *Oxford University Press, New York, 2005.*

[5] B. G. Glaser and A. L. Strauss. The discovery of grounded theory: strategies for qualitative research. *Taylor & Francis eds., 1967.*

[6] R. Godøy. Gestural-sonorous objects: embodied extensions of schaeffer's conceptual apparatus. *Organised Sound 11 (2), 2006.*

[7] R. Godøy, E. Haga, and J. A.R. Playing air instruments: Mimicry of sound-producing gestures by novices and experts. *Lecture Notes in Computer Science. 2006, 3881, 256-267.*

[8] L. Henbing and M. Leman. A gesture-based typology of sliding-tones in guqin music. *Journal of New Music Research 36(2):61-82, June 2007.*

[9] K. Höök. Designing with the body: Somaesthetic interaction design. *MIT Press, Cambridge, USA, November 2018.*

[10] C. Hummels, K. C. J. Overbeeke, and S. Klooster. Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction. *Personal and Ubiquitous Computing: Special Issue on Movement-Based Interaction.11, 8, pp. 14, 2007.*

[11] T. Magnusson. Ergodynamics and a semiotics of instrumental composition. *Tempo, 73 (287). pp. 41-51. ISSN 0040-2982, 2018.*

[12] K. Nymoen, J. Torresen, R. Godøy, and A. Jensenius. A statistical approach to analyzing sound tracings. *Speech, Sound and Music Processing: Embracing Research in India. 8th International Symposium, CMMR 2011. 20th International Symposium, FRSM 2011. 2012, 120-145.*

[13] T. Schiphorst and K. Andersen. Between bodies: using experience modeling to create gestural protocols for physiological data transfer. *CHI'04 Fringe, ACM Press, Vienna, Austria, 2004.*

[14] D. Smalley. Spectromorphology: explaining sound-shapes. *Organised Sound 2 (2), 107-26, 1997.*

[15] A. Tanaka, A. Altavilla, and N. Spowage. Gestural musical affordances. *Proceedings of the 9th International Conference on Sound and Music Computing, 2012.*