SPRINGBOARD: EXPLORING EMBODIED METAPHOR IN THE DEISGN OF SOUND FEEDBACK FOR PHYSICAL RESPONSIVE ENVIRONMENTS

Milena Droumeva

School of Interactive Arts and Technologies
Simon Fraser University
mvdroume@sfu.ca

Alissa Antle

School of Interactive Arts and Technologies
Simon Fraser University
aantle@sfu.ca

Greg Corness

School of Interactive Arts and Technologies
Simon Fraser University
gcorness@sfu.ca

Allen Bevans

School of Interactive Arts and Technologies
Simon Fraser University
abevans@sfu.ca

ABSTRACT

In this paper we propose a role for suing embodied metaphor in the design of sound feedback for interactive physical environments. We describe the application of a *balance* metaphor in the design of the interaction model for a prototype interactive environment called Springboard. We focus specifically on the auditory feedback, and conclude with a discussion of design choices and future research directions based on our prototype.

1. INTRODUCTION

As computing becomes embedded in the physical environment, issues of embodiment, situatedness and phenomenological presence emerge in the fields of technology and interaction design [1]. Philosophy of embodiment offers an ontological basis for thinking about such issues [2, 3], however, it is the crossover between cognitive science and human-computer interaction (HCI) that holds the most fruitful starting points for investigation, both empirical and design-based into new forms of physical computing. The study of metaphor, specifically physically-based embodied schemata, as articulated by Lakoff and Johnson [3], has gained popularity in the HCI field, however both empirical research studies and practical design endeavours are few to be found. Understanding how metaphors may be used in the design of interactive [learning] systems still requires much investigation [3,4,5]. We focus on the ways in which metaphors may be used in the context of physical responsive environments particularly ones using informative sound feedback. In this paper we'll focus specifically on the conceptualization and design of sonic feedback by providing theoretical background, briefly describing our working prototype of Springboard and our iterative design explorations of auditory feedback.

In previous work we have already explored the idea that conceptual metaphors, derived from embodied schemata and operating outside of conscious awareness, could be used to create systematic and salient relationships between specific human actions and specific system responses [4, 5]. Based on our investigation of a physical interactive audio environment called SoundMaker [4] we found evidence that an embodied interactional model made the system easier to learn to use and resulted in a more enjoyable experience. In order to validate our initial findings and extend our work with metaphor to visual as well as auditory modalities, we have created another interactive environment, called Springboard. Springboard is a room-sized interactive environment where users can explore issues in social justice through balancing their bodies in space. Springboard is a research instrument that will allow us to continue to empirically investigate the details and benefits of embodied interaction in embedded computational systems. We the see contributions of this paper to the auditory display community being in large the introduction of the notion of metaphor from embodied cognition into auditory display design practice. Using 'embodied metaphor' as a starting point for conceptualizing cognition and perception in particular auditory contexts provides a new and thus far underexplored perspective into the field of auditory displays.

2. THEORETICAL FOUNDATIONS

Our focus around embodiment and sound in this paper is to better understand how physical, whole-body interaction with a given designed environment influences auditory perception, the experience of a soundscape and its conceptual interpretation. Such an inquiry clearly necessitates a multi-disciplinary perspective. The fact that listening is an *embodied* activity is not a novel one. Many philosophers and cultural theorists have already talked about sound being an embodied, experiential activity, a modality that is pre-conceptual and resides primarily in the body [6, 7, 8].

With regard to sonic aspects of metaphor specifically we rely on two sets of ideas – perceptual and experienced metaphor. Introduced by Budd [8], Roger Scrutton's seminal work on metaphorical aspects of musical perception posits that the difference between hearing sounds and their sonic parameters (pitch, tempo, amplitude) versus hearing music and musical elements (such as tone, rhythm, melody and movement) is that the latter necessitates a metaphorical interpretation, without which we cannot hear a "tone" or a "melody" per se. On the other hand, the Dalcroze Eurythmics method of teaching emphasizes bodily movement as a metaphoric representation of musical concepts [7].

Rather than having a ready framework based on theories of embodiment and sound, we use the above mentioned literature as guiding and inspirational principles to which we try to stay faithful as we attempt the adapt a 'metaphorical' sound feedback representing 'balance' to our system.

3. SYSTEM DESIGN AND IMPLEMENTATION

3.1. The Springboard Interactive Environment

We based Springboard's interaction model on the metaphorical extension of the twin-pan balance schema presented by Johnson, where concepts in social justice and can be either balanced or imbalanced in two ways (too much, balanced, too little). The environment supports users to interactively explore representations and sounds related to three social justice issues

– food allocation, conflict resolution and consumerism. As an example, in the conflict resolution example, a balanced state could be a peaceful protest, while the two extremes could be either a military dictatorship or an ideological compliance.

The active input space is a small raised platform (132 x 71 x 20 cm) made from a crib mattress spring, board and black cloth. States of bodily balance are determined as users move their body's centre of gravity and spatial position on the springboard input platform. The bodily balance of the user is determined using a blob tracking and analysis computer vision system developed in the Max/Jitter programming environment. The participant stands in front of a black background on the black platform. The total balance of the participant is calculated using a body centre of gravity balance index and a positional balance index and is used to control the image and sound reasoning and display engines.

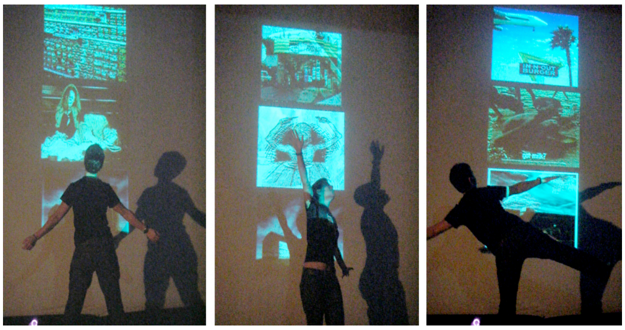

figure 1. Springboard input and image display space.

The sound feedback for Springboard necessitated an investigation into the different ways in which balance may be represented through a sonification-type parametric feedback change. However, literature suggesting salient perceptual (let alone metaphorical) mappings to "balance" is hard to come by. The following sections describe the process we engaged in in order to design and workshop approaches to embodied metaphorical representations of balance through sound feedback.

3.2. Sonification and Metaphor

While Johnson and Lakoff [3] mostly deal with linguistics and visual perception as loci for embodied schemata examples, we attempt to tackle how embodied schemata might link auditory perception with body movement in order to reinforce a metaphorical relationship between physical structures of *balance* with the abstract notion of *balance* in a higher-level concept such as justice. General evidence of sound perception being related to embodiment can be found in music education and psychology literature [7, 8] as well as in the field of embodied cognition [6] and interaction design [5]. Case studies and sound design technique papers focusing specifically on representing "balance" through sound could be found in the field of kiniseology and rehabilitation [9] as well as in the sonification and auditory display literature [10, 11, 12, 13]. While articles explicitly investigating metaphorical links between embodiment, conceptual reasoning and auditory feedback seem to be lacking, expanding the search to sonification literature provides more examples.

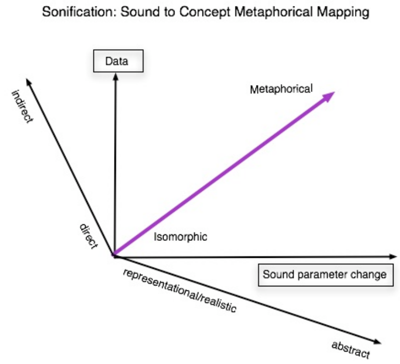

figure 2. A schematic showing sonification as a gradient representational metaphor

Essentially, sonification of data provides degrees of metaphorical representations between concept and feedback (see figure 2). The data-to-parameter mapping could be isomorphic as in the case of directly sonifying motion [9, 10, 12] or more relative, as in the case of increasing pitch with the increase of data values [13]. It could also be more metaphorical, resting on experiential qualities of physical objects, as in the case of decreasing pitch with the increase of pressure, as larger mass is metaphorically associated with lower tones [14]. Furthermore, sound used to sonify parametric change could be more realistic or more abstract (in its likeness to the original sound source, or in its representation of sound behaviour) – as in the case of representing velocity in a balancing task [13]. There, authors found that even filtered noise, used in conjunction with a physical simulation gave strong cues to listeners for balancing a virtual ball on a twin-pan tilt-rod. In another case study from a recent paper by Brungart and Douglas [11], low-pass and spectrum filtering manipulation of even complex sounds such as pilot-selected music tracks gave reliable and effective pressure cues in airplane operation. A closing of the filter was a strong cue for the plane losing pressure and sloping down, while opening the filter was linked to understanding the plane as drifting up, due to a pressure fluctuation.

3.3. The Springboard Sound Feedback Model

One of our design intentions for the sound feedback was that it provides constant ambient information, responding to user actions as they fluctuate in and out of achieving a "balanced" state. Thus, a clear granularity of change was one of the most important design challenges for us to approach. It is important to note that the "obvious" choice of a Left-Right channel cross-fade (panning) was discarded early on as a representation of "balance". Instead, we focused on more perceptually-based sound parameter changes such as pitch, timbre and phase, in order to achieve a sense of sonic balance. While there is not much literature linking the concept of balance with sound through metaphorical transformation, there are general guidelines in the literature on sofinication [14]. Through them and some of our own bodystorming exercises we came up with three main metaphorical approaches of representing balance through sound: BALANCE as tuning, BALANCE as clarity and BALANCE as movement. All baseline soundscapes that we decided to use are drone-like abstract musical compositions, the reason for our choice being that they best work with parametric change.

3.3.1. Balance as tuning

Since pitch is one of the top choices in sonificaiton, for its perceptual saliency, and it has been discussed extensively for its metaphorical relations to spatiality and embodiment [14, 12] we made pitch-based change one of our first options. Because we are working with a twin-pan schema, pitch allows us to go in two directions of balance – one where the sound is lower than normal and one where the sound is growing higher than normal. Normal is defined here as the default value of 1 (original sound) of file speed in Max/MSP.

3.3.2. Balance as clarity

Out of some preliminary bodystorming we came up with the notion of "clarity" as a state of sonic balance. We use it here to allude to the notion that balance in a sound could metaphorically be understood as a contrast between when it sounds "normal" and when it is "obscured", "unclear" or otherwise "sounds wrong". Phenomenologically, it could be related to our own soundmaking at times when we experience it as unusual – e.g. when we have a cold and our voices are affected by it. Using the process of low-pass filtering, attenuating or de-attenuating different frequency "bands" perceptually results in a sound being thought of as sounding either "tinny" or "full" or "muffled" (fitting into our twin-pan balance model), while returning all its frequency bands to a normal state should result in a "balanced" sound. Similarly, we also used a phasor object in Max/MSP to explore a more rhythmic sensation. By varying its value the phasor object loop-plays an increasingly smaller or larger portion of the original sound, resulting, at high values, to a pulsating impression. When the person is in a balanced state users will hear the sound in its entirety, at regular tempo and pitch.

3.3.3. Balance as movement

Perhaps the most interesting and salient observation to come out of our bodystorming process was the realization that more so than the type of parametric change in a sound, it was the pattern, range and frequency of "movement" within the sound that really resonated with body movement in space. One approach to this 'movement' metaphor, in terms of parametric change, was an expanding and contracting ramp of a filter sweep through a given sound drone. To achieve this we used a low-pass filter whose Q value swept from 500Hz to 8000Hz controlled by a metro, which itself had a range between 5 and 25 miliseconds of sweep duration. This effect was reportedly felt in the body as a range of differently sized concentric circles around a pivotal point, so it seemed like a good contestant for the notion of balance. We recreated a similar movement pattern using the same process with a pitch ramp and a phasor ramp, resulting in similar embodied experiences during our bodystorming. The next step for us was to organize a small design workshop and solicit the feedback from a few participants in order to reinforce, eliminate and generally better understand our chosen approaches to creating a metaphorical link between sound feedback and an embodied notion of balance.

3.4. Participatory Workshop and Results

For the workshop we had six participants who were asked to listen to a series of seven sound examples and represent the sense of "balance" they get from the sounds by moving their bodies in space. We took observational notes of their body motions, gestures and spatial movements in order to uncover common responses. Both during the workshop and afterwards participants were queried with a loose *Talk Aloud* protocol to describe their immediate experiences of embodiment and sound perception. Table 1 illustrates the approaches to representing balance through sound that we tested, organized by type of change and approach to representing "balance". Aside from white noise, we used several pre-composed abstract musical drones as sound examples. The parametric changes were generated using Max/MSP software, recorded into files and played back. Each example followed a pattern of states as follows: balance – off-balance A – balance – off-balance B – balance (where A and B refer to the two ends of the fulcrum).

Balance - Sound Examples	**Parameter**	**Experienced as**
Noise low-pass sweep	Spectrum	Timbre change
Noise train	Spectrum + Modulation	Phase variation + timbre change
Pitch sweep (up-normal-down)	Pitch	Out-of-tune
M1 low-pass sweep	Spectrum	Timbre change
M2 Phasor Modulation (slow-fast-slow)	Phase	Pulsating tempo change
Movement – based Balance - Sound Examples		
M1 Low-pass ramp (up-down, slow-fast)	Range of filter values	Tempo of timbre change
M2 Pitch ramp (small-big)	Pitch ramp range value	Degree of off-tune ramp

Table 1: Breakdown of the workshop protocol. M1,2,3 refer to Melody 1, 2 or 3 used in the workshop. Melodies were pre-composed drone-line abstract musical compositions.

Table 2 below summarizes some of the common body movements that participants performed and some of the emerging metaphors that they utilized in describing their experience of sonic balance. While so far in our system we had provisioned for center-of-gravity and lateral sideways movement representation of balance, participants performed a variety of additional types of movements including high-low, forward-backward, swaying in place, twisting, contorting and rotating motions. In addition there were some gestural elements – whole arm or hand movement following a melodic line or rhythm; as well as head and neck movements. Many participants commented on the sound pushing or pulling them in different directions with different tempo and force. In several of the sound examples, participants found a sense of 'tension' and a satisfying return to a "normal state". There were only two instances where participants truly felt a sense of "balance" – the single sound pitch change (high and low), and the phasor sweep (pulse and tempo). The filter-based sweeps generated more vertical movements and opening-closing gestural/trunk motions. The rest of the sound examples were experienced as primarily about "motion" as opposed to about "balance". What that meant to participants was that the embodied representation of sonic changes were primarily about the quality, directionality, force, tempo and sense of the motion itself.

Balance - Sound Examples	**Body Movements**	**Described as**
Noise low-pass sweep	Low/high motion, sound pushing, backward/forward	Expanding/ContractingForce

Noise train	Fluid movement, swaying, gesture	Motion, Fluidity
Pitch sweep (up-normal-down)	Contorting, sideways twisting, Up-down sway	Balance / out of Balance, Verticality
M1 low-pass sweep	Sideways twist, Sound pulling	Force, Tension
M2 Phasor Modulation (slow-fast-slow)	Side to side, slow-fast	Rhythmic motion
M1 Low-pass ramp (up-down, slow-fast)	Freeform movement, sway and swirl, tempo	Motion, Force
M2 Pitch ramp (small-big)	Reaching up/down, back/ forth, twisting	Expanding/Contr actingBalance/ out of Balance

Table 1: Breakdown of the workshop results organized by common movements participants used and words they used to describe the sense of "balance".

Perhaps the most significant finding to come out the participatory workshop was the fact that participants did not intuitively perceive the sonic representations of "balance" or even "motion" as a twin-pan fulcrum, but rather as a duality between balance vs. out-of-balance; weight vs. freedom; tense vs. relaxed; tight vs. loose; smooth vs. choppy; inward vs. outward; comfortable vs. uncomfortable. While these reveal a metaphoric transference between concept and body movements strengthened by sonic qualities of parametric change, they still manifest as dualities. However, when participants were queried further, it became clear that a simple duality on a linear plane did not quite capture their embodied experience either. There was agreement that almost any parametric change had a quality of having a "normal" state and various states of being disrupted, modulated, unbalanced or otherwise "not-normal". This led us to suggest that perhaps a better representation of a visual distribution of sonic "balance" may be a sphere, and not a fulcrum – as shown in figure 3.

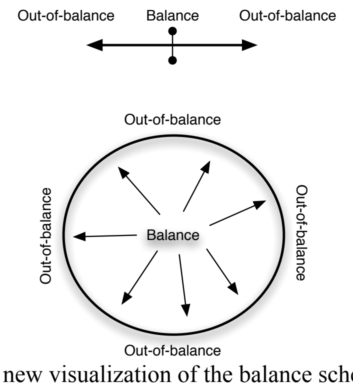

figure 3. Our new visualization of the balance schema of sound.

4. CONCLUSION

Designing an interaction model and implementing the sensing and reasoning system based on an embodied metaphor is difficult and relies on several important design decisions. The choice to use the twin-pan balance schema was driven by the focus on justice, in which the scales (twin-pan) are a dominant concept. The choice of sensing centre of gravity and spatial location on the platform in order to determine states of bodily balance was largely driven by bodystorming exercises and exploration of different structures that would cause users to move in balanced and unbalanced ways. Future user studies will be required to test and tune the prototype before experimental work can be undertaken.

In the current paper we have attempted to link embodied metaphor with sound feedback in a design-based case study. We have elaborated on our iterative process attempting to uncover metaphorical linkages between body movements and parametric sound change in the understanding of abstract concepts within an interactive physical computing environment. We propose that this work could serve as a starting point towards a larger discussion into the merits of leveraging embodied metaphor in the design of sound feedback for physical computing systems.

5. REFERENCES

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