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Sonic Microinteraction in "the Air"

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Abstract

This chapter looks at the ways in which micromotion, the smallest controllable and perceivable human body motion, can be used in interactive sound systems. It presents a general taxonomy, followed by examples of how sonic microinteraction was designed and rehearsed in the scientific-artistic project *Sverm*. Here, the focus was on micromotion and microaction performed in "the air," but the concepts developed by the project can also be transferred to other types of microinteraction.

1 Introduction

Try to stand still for a couple of minutes. What do you observe? How still can you actually stand? Do you notice the continuous motion of various parts of your body—the rhythmic patterns of your breathing, pulse, and postural adjustments, for example? As a living organism, your body is constantly in motion, even when you try not to move. Researchers have even demonstrated that when people try to stand still on the floor, their heads—the part of the body furthest from the balancing feet—typically move at a velocity of around seven millimeters per second (Jensenius, Bjerkestrand, and Johnson, 2014). Such a quantity of motion might thus be considered the "base level" of a human at a supposed standstill. Following from this, we can propose three rough spatiotemporal levels of human action:

1. *Micro*: The smallest controllable and perceivable actions, happening at a scale just above the base level—that is, measured in millimeters per second.
2. *Meso*: Most sound-producing and sound-modifying actions, such as moving the fingers on a keyboard (see Jensenius, Wanderley, Godøy, and Leman, 2010, for an overview of music-related motion). These actions unfold at a scale measured in centimeters per second.
3. *Macro*: Larger actions, such as moving the hands, arms, or entire body, at a scale measured in decimeters or meters per second.

This chapter will look at some of the principles involved in how we might develop conceptual methods and technological systems concerning *sonic microinteraction*, a type of interaction with sounds that is generated by bodily motion at a very small scale. Here, I use "micromotion" to denote the continuous displacement of an object in time across space at the micro level. “Microaction,” on the other hand, describes a motion segment that is goal-directed and/or intentional, again at the micro level. The exact velocity of the “small” motion/action is not the priority at this time; the focus is on human motion on the very boundary of what is controllable and perceivable. As such, my definition of microinteraction differs slightly from other definitions used in human-computer interaction, such as Ashbrook’s (2007) use of the “4-second bursts” of interaction from Oulasvirta, Tamminen, Roto, and Kuorelahti (2005) to describe “microactions” that take less than four seconds from initiation to completion. In the terminology used in this chapter, such four-second mobile phone–related actions would fall within the meso range. This chapter, however, will focus on the conceptualization of interactive systems that can exploit the smallest possible micromotion that people are able to both perceive and produce. It is also important that the interaction that is taking place allow for a recursive element via a feedback loop from the sound produced back to the performer producing it (di Scipio, 2003).

2 Acoustic versus electronic instruments

One reason to start investigating microinteraction from a musical perspective is that regular musical performance on acoustic instruments falls, to a great extent, within the definition of sonic microinteraction. Consider, for example, the microinteraction involved in the fingers of a violinist or the lips of a saxophonist. In this chapter, however, the focus will be on the possibilities of microinteraction related to *electronic* systems, and particularly to *digital musical instruments* (DMI). While there are many examples of sonic microinteraction in acoustic instruments, there are relatively few cases of such “intimate” control in relation to DMIs (Wessel and Wright, 2002), which instead tend to rely on mesointeraction. Notable exceptions include the SoundPlane (Jones, Driessen, Schloss, and Tzanetakis, 2009), the Plank (Verplank, Gurevich, and Mathews, 2002), and the Roli series of keyboard-like instruments (Lamb and Robertson, 2011).

There are probably several reasons why we (still) do not find many examples of microinteraction in DMIs. It is easy to blame the Musical Instrument Digital Interface (MIDI) protocol, which has been under continuous attack from the music technology research community almost since its release (Loy, 1985; Moore, 1988). We should remember, though, that many of the original limitations of MIDI (such as speed, bit depth, and number of channels) have been improved over the years. Alternative protocols have also been available for almost two decades, with Open Sound Control (OSC) being the “unofficial” standard within the computer-music community (Wright, Freed, and Momeni, 2003). Still, most commercial digital music controllers (such as MIDI keyboards) and many experimental controllers are built around a meso-level “button/knob/slider” paradigm, even though it is technically possible to build things that are smaller and faster. This may be because many developers and users perceive *meso*interaction to work adequately in most cases.

Paradoxically, though the size of electronics has decreased over the last decades, their interaction modalities have increased. So rather than moving toward microinteraction, we have ended up with more *macro*interaction. This could be explained by a general cultural focus on “gestural” controllers, meaning those that focus on large-scale interactions (see Jensenius, 2014, for a discussion of the term “gesture” in relation to interactive music systems). An example of such a large-scale, and comparably slow, interaction type is the use of full-body motion capture system for interactive music and dance (Dobrian and Bevilacqua, 2003; Skogstad, Jensenius, and Nymoen, 2010). This type of interaction may be attributed to the widespread availability of new technologies that afford fairly large-scale interaction modes (for example, the Wii and Kinect). Their limitations, in turn, may partly be due to technical constraints related to the temporal speed and spatial resolution of the devices. However, more expensive inertial and optical motion tracking systems are certainly capable of tracking below the spatiotemporal thresholds of human body motion (Jensenius, Nymoen, Skogstad, and Voldsund, 2012). It thus appears that the main reason for the apparent lack of focus on microinteraction in the music technology community may be conceptual rather than technical. The challenge, then, is to figure out whether and how micromotion might be meaningfully used in sonic interaction design and musical performance.

3 From motion to standstill

The approach to microinteraction presented here originally grew out of research into macrointeraction in full-body motion capture systems and large-scale interactive dance and music pieces. In fact, many interaction projects are concerned with the macro level, whereas relatively little had been done with the micro level. Of course, music acousticians have focused on micromotion in instruments for a long time, and there is some knowledge of micromotion in the medical and rehabilitation literature. But from a *gestural* perspective—a field that has been blossoming in recent years in both music (Wanderley and Battier, 2000; Gritten and King, 2006, 2011) and linguistics (Kendon, 2004; McNeill, 2005; Goldin-Meadow, 2003)—the focus has mainly been on mesomotion and macromotion.

One exception here is the psychological interest in facial micromotion, or what has been termed *microexpressions* (Ekman and Friesen, 1969). Such microexpressions—for example, small and rapid motion in the lips—can be used to help determine when people are lying. Likewise, research on micromotion in the eyes—for example, microsaccades, drifts, and tremors—has demonstrated that our eyes are always in motion (Martinez-Conde and Macknik, 2007), and that microsaccades in particular are related to our mental re-creation of visual scenes (Laeng and Teodorescu, 2002). But how might these microexpressions and others relate to music?

To understand more about micromotion, I embarked on a study of human standstill through the scientific-artistic research project *Sverm*. My aim was to look at the “absence” of motion, as the starting point for the study of micromotion. I teamed up with dancer-choreographer Kari Anne Vadstensvik Bjerkestrand, who has extensive experience working with intricate and slow movements (such as Tai Chi Chuan). Together we undertook a pilot study consisting of fifteen sessions of standstill, each ten minutes long, during which we simply stood in silence on the floor (Jensenius and Bjerkestrand, 2012). Each session was recorded using a high-quality motion capture system, and we also took notes and discussed our subjective experiences of standing still.

As one might imagine—and as has been revealed in previous studies of the “human pendulum” (Collins and De Luca, 1994)—it is not in fact possible to stand absolutely still. As one tries to do so, one immediately begins to experience the swaying in the body, the shifting of weight between the legs, and various ongoing biological processes such as the heart beating, breathing, and swallowing. Quantitatively, we found that our heads moved at a rate of 4–9 mm/s, calculated as the first derivative of the magnitude of the position vector (Jensenius and Bjerkestrand, 2012). This result was confirmed in a follow-up study of a group of five people who stood still in silence 25 times, again ten minutes at a time (Jensenius et al., 2014). To extend the project to an even larger group of people, we organized the “Norwegian Championship of Standstill” in 2012. About one hundred people of all ages participated, and again we found that the quantity of head motion of the participants averaged around 7 mm/s.

How *much* people move when standing “still” is one thing, but more interesting from a sound and music design perspective is *how* they move. Careful analysis of the project’s standstill data revealed clearly person-specific patterns in the data sets (Jensenius and Bjerkestrand, 2012). First, at the temporal micro level, we could see quasi-random motion happening at the scale of milliseconds that might have been caused by the swaying of the body as the ankles work to keep the body in balance (Loram and Lakie, 2002). At the temporal meso level, there was periodic motion with a frequency of approximately five seconds that likely corresponded to respiratory patterns. These patterns were more systematic and individual, to such an extent that it was possible to identify the individual solely through the plots of this micromotion. Lastly, at the temporal macro level, there were person-specific patterns, such as “spikes,” at regular intervals that could be explained by postural adjustments or periodically larger inhalations. Despite the fact that there was some “noise” in the data, then, there was also much meaningful information to be exploited via interactive systems.

4 From standstill to micromotion

Since our everyday lives are filled with motion and relatively large-scale interaction, standing still for a few minutes is an efficient warm-up exercise, because it pushes the body and its senses into a mode from which it is easier to sense and work with small body motion. In other musical practices, warm-up exercises can focus on increasing the mobility of fingers or getting the air flowing through the vocal apparatus. While such approaches are also relevant for microinteraction, it is even more important to physically and mentally connect with one’s own micromotion at the boundaries of standstill.

My experience is that it does not take very long to become comfortable with standing still for an extended period of time. Many people find it somewhat awkward the first few times but usually report that they enjoy the experience in the end. It can help to systematically test different physical and mental strategies that modify the experience of standing still, such as:

- different body postures (open/locked knees, changing arm positions, etc.)
- room positioning (standing in the center, toward the wall, etc.)
- visual experience (keeping the eyes open versus closed)
- auditory experience (listen to music versus silence; utilizing “active” versus “passive” listening modes)
- mental tasks (none, meditation exercises, playing number games, etc.)

The aim of such a systematic exploration of different ways of standing still is to experience the boundaries between the involuntary micromotion happening in the body due to breathing, pulse, and so on and the voluntary micromotion that might eventually lead to microaction. In this context, it is preferable to use the terms *voluntary–involuntary* as opposed to *conscious–un/subconscious* in order to avoid the philosophical or psychological complexities of the topic of consciousness (Baars, 1993). That said, we must remain aware of the many challenges of working at this level of control, from both a physical and a psychological point of view.

Once one masters the act of standing still comfortably, one can start exploring the micromotion happening in one’s body. A key strategy related to moving from a standstill is to follow along with any small changes happening in the body. As with larger-scale improvisation, it is important go with the flow of the “performance” and embrace the motion possibilities that are presented. It is time, in short, to start “microacting.”

5 From micromotion to microaction

Recall that, in this chapter, *action* denotes a self-contained motion sequence with a more or less well-defined beginning and ending in time. Actions can be goal-directed (such as hitting a piano key or opening a door) or performed freely or haphazardly (such as waving one’s arms in the air). Actions are usually performed voluntarily, although exceptions occur—reflex actions, for example, are among the most well-known involuntary actions.

To best work with microactions systematically in the *Sverm* project, we found it necessary to develop precise descriptions of the different types of actions to be performed. Table 1 presents three spatiotemporal levels—that is, micro/meso/macro in both time and space. The ranges are indicative rather than definitive. Using these levels, we can create a matrix among the various spatial and temporal dimensions, as outlined in the example in Table 2. Such a matrix can be used to describe actions with specific spatial and temporal properties. For example, a “micro–micro action” might be thought of as an action in micro-space (less than one centimeter) and micro-time (shorter than 0.5 millisecond), whereas a “micro–macro action” would be a small action carried out over a long period of time (from minutes to hours). If this is a somewhat coarse method of describing human actions, it proved effective nevertheless for practicing and performing different types of actions in music and dance contexts in the *Sverm* project.

	Space	Time
Micro	<1cm	<0.5s
Meso	1–50cm	0.5–10s
Macro	>50cm	>10s

Table 1: Overview of the categories of spatial and temporal levels (approximate values).

		Time		
		Micro	Meso	Macro
Space	Micro	1		
	Meso		3	
	Macro	2		

Table 2: An example matrix of possible spatiotemporal combinations. The numbers indicate the order in which actions should be carried out: (1) micro–micro, (2) macro–micro, (3) meso–meso.

Just as a musician would need to practice scales in all keys to become acquainted with various melodic progressions, one must investigate all of the possibilities to understand the spatiotemporal matrix as well. We spent much time in the *Sverm* project systematically exploring the nine spatiotemporal action combinations for different parts of the body: foot, hand, upper body, head, and so on. We did so mostly by moving in “the air,” and thus producing no sound. Predictably, it was the most extreme contrasts that were the most difficult to master, such as the combinations of micro and macro. But they were also the most interesting, particularly because they also stretched our capacity for “mental imagery” of the involved actions, or our imagined actions (Godøy, 2001). When carrying out a macro level action, for example, it helped to mentally “overshoot” the action—that is, to imagine an action that was even greater than the one to be physically produced.

After much practice with micro–macro actions, such as moving a finger one centimeter over the course of ten minutes, it became apparent that these actions evoked the continuous *state* of standing still. At first, it was not immediately clear whether an observer could even spot the difference between a state and a micro–macro action. From the performer’s perspective, however, carrying out a micro–macro action is not at all the same as performing a state. It is very different to walk on stage with the intention of standing still for ten minutes than it is to carry out a small ten-minute-long action. In our experience, as well, this difference in the performer's intention and attention is in fact clearly visible to the observer.

There are also numerous challenges related to clearly distinguishing between voluntary and involuntary actions, such as the act of breathing. In one sense, breathing can be seen as part of a state—it is something continuously happening, unconsciously and involuntarily. But it can also be seen as an action—something we do consciously, when we take a deep breath for example. The act of breathing can further be subdivided into two main components—breathing in and breathing out—with one or both being performed voluntarily, so that it is possible to focus very explicitly on breathing in, then just let go and breathe out unconsciously. Exploiting such dualities with their built-in tensions might suggest some artistically interesting applications.

6 From microaction to sonic microinteraction

After mastering the skill of executing different types of microactions, we were finally able to apply them in interactions with sound, or what we called *sonic microinteractions*. We might see these as a subset of *sonic interaction design*, a field that has been positioned at the "intersection between sound and music computing, interaction design, human-computer interaction, new interfaces for musical expression, product design, music psychology and cognition, music composition, performance and interactive arts" (Hermann, Hunt, and Neuhoff, 2011).

Sonic interaction design is about creating what might be called *action–sound relationships* in interactive systems, as distinct from the action–sound *couplings* that we find in nature (Jensenius, 2013). This differentiation does not imply a value judgment at the expense of the interactive qualities of electronic devices. Instead, it simply observes that there are physical, conceptual and perceptual differences between couplings and relationships, and that being aware of these differences can help us when we are designing, using, and studying sonic interaction. Here it is important to remember, as well, that the action–sound couplings we find in acoustic instruments are based on the physical properties of the objects and actions involved. Furthermore, such couplings abide by the laws of nature, whereas relationships are designed and constructed and therefore can be "limitless." For example, playing on an acoustic piano will always produce "piano-like" sounds—that is, sounds that, no matter how various, are based on the instrument's physical properties. A digital piano, on the other hand, can produce the sounds of a flute, a violin, rain, and so forth, even with exactly the same key-pressing action. Such an extended "palette" of possible action–sound relationships is something to which we have grown accustomed, and we are therefore not particularly surprised to hear flute sounds coming out of a digital piano. This is, in short, the conceptual and perceptual difference between a coupling and a relationship.

My claim is that the efficient design of action–sound relationships should be informed by the properties of similar action–sound couplings. This alignment works well when one is dealing with electronic systems that can resemble physical objects. It is more difficult when one is designing action–sound relationships for hand motion in the air, for which there are no actual acoustic sounds. What types of sound qualities might we then build on when designing the sonic microinteraction for a system or device?

Our approach to creating ecologically plausible yet artistically interesting sound designs in the *Sverm* project was to start out by exploring sonic microinteraction using vocal "prototyping." We worked in pairs, with one person carrying out the microactions and the other creating a sonic correlate that "imitated" the microaction. We used the matrix approach as described above (Table 1) to systematically explore different types of sound-producing actions at the micro level, and particularly the aforementioned two extreme cases:

- micro–micro: small and short actions, resulting in impulsive sounds with a “quiet” sound quality
- micro–macro: small and long actions, resulting in sustained sounds with a grainy, almost iterative sound quality

Obviously, due to the relatively low energy involved in both of these excitation types, the resultant sounds had both low volume and a “dull” sound quality. Also interesting was the fact that the micro–macro actions tended to result in friction-like sounds, and sometimes even an iterative type of sound with successions of short, impulsive sounds.

Based on the experience of this acoustic “prototyping,” we began to explore sonic microinteraction using real-time tracking from an infrared marker-based system. Here, we explored sound models with similar qualities to what we had found using the voice, such as the friction models of Serafin (2004) and the microsound models of Roads (2004). This effort eventually transformed from a systematic and scientific investigation to an artistic process, because one of the goals of the *Sverm* project was to work toward the realization of a music/dance performance.

7 From lab to stage

In addition to the more “ecologically informed” sound designs mentioned above, we also experimented freely with different types of action–sound relationships. All of this work eventually boiled down to three concrete designs that we found to be particularly interesting from an artistic perspective, which we named “Friction fraction,” “Waving sines,” and “Granulated violin.”

The sonic microinteraction design called “Friction fraction” was based on directly mapping the quantity of motion of a body part to a physically inspired model (metashaker~ from the Percolate collection for Max). This is a very direct and intuitive mapping that is easy for a performer to control and easy for an observer to understand. Despite the straightforwardness of the mapping, the physically inspired sound model ensured both richness and variation in the sound being produced.

The “Waving sines” mapping was based on sonifying the continuous motion of the head markers of five performers using sine tones. Here, we decided to use the inverse quantity of motion to control the amplitude of the tones, so that the sound’s loudness would increase as the performers stood more still. In addition, we experimented with controlling the pitch of the tones through the tracking of the vertical positions of the performers, and the horizontal motion of the performers was used to diffuse the sounds in space using vector-based amplitude panning (Pulkki, 1997). This meant that the sounds appeared to come from the position in space of each performer. The end result was a series of fluctuating, throbbing patterns between the sine tones that derived from the involuntary and voluntary microactions of the performers in space. This design was conceptually simple, albeit less ecologically inspired, and it turned out to be profoundly interesting to both performers and perceivers. For the performers, it was truly a challenge to focus on standing as still as possible, even as their standstill represented the source of the increased sound. Due to the sensitivity of the motion tracking system, this very direct yet “unnatural” feedback loop forced the performers to work very hard to focus on standing still. This physical and mental struggle was something that several audience members remarked upon.

The “Granulated violin” design followed up on the idea of granularity in both motion and sound. Since one of the performers in *Sverm* was a violin player, we decided to use a five-second sample of a single violin stroke as the source material for a granulator, using FTM for Max as the sound engine (Schnell, Borghesi, Schwarz, Bevilacqua, and Müller, 2005). The sound playback and the granulator’s settings were controlled using the three-dimensional position parameters tracked from one of the performer's head markers. This made it possible for the performer to control in real time three individual granulation parameters (playback location, grain size, and grain spacing), while the general quantity of motion of the marker was used to control the sound level. In the final performance, this became a striking end to the show, in that the dancer's microactions were used to control the continuous violin-like sound texture, whereas the violinist herself simply stood in silence, watching the dancer.

8 Conclusions

As a partly scientific and partly artistic endeavor, the *Sverm* project culminated in a forty-five-minute show that was performed over eight nights in November 2012. Clearly minimalist in nature, the show consisted of different "pieces" focused upon standstill and microinteraction with sound and light. Because standstill was the conceptual starting point, we were careful to introduce the interactive sound and light aspects very slowly and subtly into each piece, so that we could preserve the focus on the standstill and silence throughout the show. All in all, this made for a very limited, yet effective, presence and generated positive comments and reviews. Many audience members found that they were "moved" by the performance, and that it had been surprisingly emotional for them. It was also interesting to hear that many audience members also found the electronic elements to be very subtle, yet highly expressive. This can probably be explained by the feedback loop of motion controlling sound that would in turn influence the performers' motion. Several audience members also expressed their gratitude to the performers for creating a quiet and calm space at an otherwise busy time in their lives.

In the end, the project generated a set of sonic microinteraction designs, some that were used in the initial performance, others that have been saved for future performances. More important than the designs themselves, though, was the development of a methodology for approaching microinteraction from a performance perspective. Through the process of "learning" to stand still and the formulation of the spatiotemporal matrix, we managed to develop a vocabulary and method that could be used in artistic practice. Based on the insights and experiential knowledge produced by this project, we will next explore whether and how to use the same ideas in more general interactive systems. Many current interaction systems are based on discrete actions, possibly with some kind of recurrence but always with a focus on meso/macro-level discrete events. Continuous (sonic) microinteraction might be seen as one step closer to actual feedback-based systems that are evocative of our regular interaction with physical objects in nature.

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