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5 Composing with microphones and loudspeakers

My investigation in chapter 4 revealed that, although microphones and loudspeakers can acquire characteristics similar to those of musical instruments when there is interaction between performer, and microphone and loudspeaker, they never manage to behave entirely like conventional instruments. As I argued at the beginning of chapter 2, until the invention of sound reproduction technology at the end of the nineteenth century, music had always been produced with instruments. Probably because of this strong relationship between music and instruments, many artists working with microphones and loudspeakers approached these devices "as musical instruments", as a natural offshoot of the entire instrument paradigm. The wish to compose for microphones and loudspeakers as if they were musical instruments may be considered as an extension of a specific view of music, a relatively conservative one in that it is implied that new means like microphones and loudspeakers should not result in a new kind of music. In my view, however, it is exactly this effort of transforming these new devices into musical instruments that has resulted in highly interesting music, as revealed by the examples in the previous chapter. It might therefore be exactly the impossibility of reaching the goal of transforming these devices into "real" musical instruments which led to solutions for microphone and loudspeaker use radically different from the practice of conventional instruments. Besides this, many of the artists discussed in the previous chapter were acutely aware of the impossibility of interacting with microphones and loudspeakers in the same way as with conventional instruments. David Tudor*, for example, mentions that the loudspeaker sculptures should "decide themselves" how to sound, in contrast to conventional instruments where the performer controls their sound as precisely as possible. The search for various modes of interaction between microphone, loudspeaker and performer has therefore not been unsuccessful by any means. The physical qualities of microphones and loudspeakers may be revealed through *interacting* by means of movement, material or space: microphones and loudspeakers become audible as sound-producing objects by either moving them, attaching objects to their diaphragm or positioning them in space.

Using the four approaches for composing

I assume that the difficulty that arises when trying to employ microphones and loudspeakers in a way similar to conventional musical instruments is the constant influence of the three other approaches, which use microphones and loudspeakers as transparent devices (*reproducing*, *supporting* and *generating*). Microphones and loudspeakers are primarily designed nowadays to function according to these three approaches. This results in resistance against becoming a conventional musical instrument, since the nature of these devices makes it quite difficult to ignore these other three approaches. This is a very different starting point in comparison to conventional instruments, which serve no other function than that of generating sounds for what is traditionally recognised as music: "[Especially musical instruments, CvE] make possible their own uses; they do not serve an interest that could have pre-existed them" (Evens 2005, 129). Microphones and loudspeakers are multi-functional devices which cannot be limited to one kind of use, which is why I classified them in the second category of objects with which to make music: objects that can produce sound but are not musical instruments in the first place (see chapter 2). Microphones and loudspeakers have many different functions, depending on the way they are approached.

I am interested in the four approaches not only as conceptual tools for analysing musical works, but also, and especially, as tools that can be put to practice compositionally. The categorisation of *reproducing*, *supporting*, *generating* and *interacting* are all theoretical classifications, whose mutual borders are not absolute; neither is it easy to find examples that fit exactly within one of these approaches. It should therefore not come as a surprise that nearly all of the pieces I discussed in chapter 4 make use of elements from other approaches alongside that of the *interacting* approach. The contact microphones used by Valerian Maly*, for example, add a resonating body to objects and, so doing, *interact* with those objects. At the same time, one hears a combination of all elements of the set-up, and the contact microphones could also be considered as *supporting* the objects they amplify. In the piece by Lynn Pook*, an audio signal is played through loudspeakers directly onto the listener's body. These loudspeakers are *interacting* with the body, but the signal they receive is not related to any specific sound source and could therefore be seen as part of the *generating* approach. In all these examples *interacting* is, thus, not the sole approach; elements of one of the other approaches (*reproducing*, *supporting* or *generating*) come into play as well. In light of this, I believe that microphones and loudspeakers seldom behave exactly as conventional musical instruments. An acoustic feedback set-up might be the closest approach to how conventional musical instruments function, but even in a piece such as *Quintet* the conventional musical instrument set-up is left behind at a certain point (see my analysis of this piece in chapter 4). Microphones and loudspeakers can be used in a similar way to musical instruments, but they will always also reveal (one of) the other approaches they are used for. This could be seen as a complication for artists who want microphones and loudspeakers to become "real" musical instruments. I would claim, however, that these multiple approaches should be seen as a characteristic feature of microphones and loudspeakers. They can be used in a way similar to musical instruments and therefore *interact* directly with performers. At the same time, they can also *reproduce* a sound that is associated with another act of sound creation, and they can *support* another musical instrument or *generate* sounds that are not related to any physical sound source at all. It is exactly this combination that makes microphones and loudspeakers unique in the field of music. To find compositional strategies specific to microphones and loudspeakers, one should therefore not search for their potential to act like musical instruments, as I did in chapter 4, but for combinations of different approaches. The works examined in this chapter no longer focus on a single approach, but on their engagement with several approaches. Whereas the *interacting* approach is obligatory to make microphones and loudspeakers "audible" in a similar way as musical instruments do, the combination with one or several of the other approaches results in a piece that is using the unique features of these devices.

Recognising the *reproducing* approach: the Edison tone tests

For the four approaches to be employable as suitable material for composing, I suggest that their application must be recognisable to the audience. This implies that the audience is able to recognise what kind of role is assigned to the microphone and loudspeaker by the composer. To illustrate how this kind of recognition might function, I will analyse two quite different musical performances in which the *reproducing* approach plays a central role.

The so-called tone tests, sponsored by Thomas Edison* and executed between 1915 and 1925 (Sterne 2003, 261–266; Thompson 1995) are the first musical performances I will consider. On stage are a singer and a phonograph. Both perform simultaneously, and when the singer stops performing, the phonograph continues alone. Apparently, it was a challenge for the audience to hear who or what is performing (Thompson 1995, 131). Of course it is more than remarkable that the audience was impressed with the results of the phonograph as compared to a real performer and even more astonishing that the audience claimed not to hear any difference. The listeners attending such a tone test were clearly not listening for the noises of the phonograph, but for hearing a reproduction of the song (Sterne 2003, 280). They knew that the noises and hisses did not belong to the music (as I illustrated with the help of the Gestalt theory in chapter 2), and hence did not hear them or, more accurately, just did not perceive them. "We are not terribly bothered by a poor recording since we are used to constructing from memory the reality of the object 'in our heads.' To hear is to remember, to recall, not to witness" (Evens 2005, 42). They knew what they were listening for, and as soon as the song and the voice of the singer were recognised, the reproduction was faithful. The audience recognises that the aim of the machine is *reproducing* a performance, and perceives it as accurate, even when this is, technically speaking, a very bad reproduction. One needs only to listen to an early twentieth-century recording to hear how much the audience must have ignored and added to what they heard.

Reproducing a sound originally produced by another source is never technically perfect. The audible result needs only to evoke a recognisable musical performance for the audience. Of course evoking such a performance is much easier if the singer and the song have just been heard live as well, as is the case with these Edison tone tests.

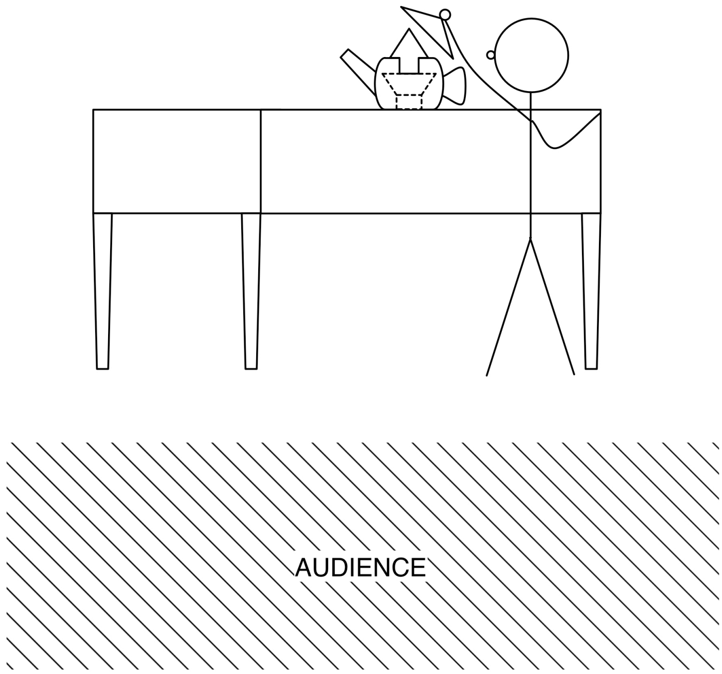
An advertisement reporting on the succes of an Edison tone test as performed the day before. A report of the tests is added, concluding: "The end of the concert found the audience absolutely and completely convinced, through its own personal experience, that there is no difference between an artist's living performance and its RE-CREATION by the New Edison, —that listening to the New Edison is, in literal truth, the same as listening to the living artists" (Anonymous 1921, 4).

Composing with the *reproducing* approach: *Nothing Is Real (Strawberry Fields Forever)* by Alvin Lucier

The use of the *reproducing* approach as a compositional strategy can be observed in the piece *Nothing Is Real (Strawberry Fields Forever)* (1990) for piano, amplified teapot, tape recorder and miniature sound system by composer Alvin Lucier* (see scheme *Nothing Is Real*). This is the second musical performance I use to exemplify how the reproducing approach might be recognised by the audience.

Throughout the first half of this piece, Lucier plays a fragmented and transposed version of the Beatles song *Strawberry Fields Forever* (1967) on a grand piano while making ample use of the sustain pedal. This manner of playing adds long resonances to the short fragments, which are played on different registers of the grand piano. These fragments are recorded during the performance. After having finished the first half of the piece, Lucier stands up and walks towards a teapot. The recording he just made is played during the second half of the performance through a small loudspeaker located inside this teapot. During the playback of this recording, Lucier lifts the lid of the teapot and lowers it again at various moments. These actions are notated very precisely in the score, since they effect a change in the sound of the playback (listen to audio examples of *Nothing is Real*). The surface of the teapot is very hard and smooth, giving rise to many different resonances, which change as soon as the resonance space of the teapot is modified by raising the teapot lid. The spatial aspects of the playback vary in response to these different resonance situations, as does the particular range of the frequency spectrum of the recording itself. The movements of the teapot lid result in sound changes reminiscent of filtering and adding or removing reverb. The teapot seems to "sing" on the resonance of the piano notes.

In both the Edison tone-tests and *Nothing Is Real*, the audience recognises immediately that the loudspeaker (or actually the phonograph horn in Edison's case) is *reproducing* a musical performance, although the sound is completely different from the original performance. The loudspeaker in the teapot is very small and will definitely not produce a high fidelity sound and, furthermore, the manipulations of the teapot lid modify the sound extensively. Nevertheless, the audience will recognise the piano fragments, since these have just been heard performed by Lucier on the piano. In *Nothing Is Real* the *interaction* approach is used as well, since the loudspeaker functions as an exciter and the teapot as a resonator to form the sound. The combination of the small loudspeaker with the teapot could almost be regarded as a musical instrument. However, the fact that it is a recording of piano music played through the loudspeaker makes clear that there is a difference between this set-up and a conventional musical instrument. Unlike all other sounding objects, loudspeakers often point to a sound source other than themselves. These other recognisable sources are what I termed the semantic



Alvin Lucier *Nothing Is Real (Strawberry Fields Forever)*: a small loudspeaker is put in a teapot. By moving the teapot lid the sound radiated by the small loudspeaker is modified.

acts of sound creation (see chapter 2)—by recognising a piano sound when listening to a loudspeaker, one recognises the "semantic source". Concurrently with the playback of the piano recording through the loudspeaker in Lucier's piece, another musical performance is taking place: the manipulation of the teapot lid. The two approaches of *reproducing* and *interacting* take place at the same time. The lifting of a teapot lid, considered in terms of a conventional instrument, might be compared, for example, to moving the slide of a trombone while playing the instrument, resulting in a glissando. The sounding result of the teapot lid movement, however, is much more complex, since the input sound (the piano recording) is constantly changing. The teapot with loudspeaker can be thought of as a transparent reproduction of a piano performance and at the same time can also be heard to produce sound which is intimately connected to the resonating qualities of the teapot itself.

The semantic source of the loudspeaker is a piano performance and not the loudspeaker itself, whereas in a conventional piano performance the semantic source remains a piano.[82] At the same time, the loudspeaker could never be replaced by a miniature piano and performer in the

[82] Of course, many instrumental pieces mimic sounds, such as the *Sonata Representativa* (1669) by Heinrich von Biber for violin. In mimetic compositions the musical instrument, in this case the violin, will never disappear. The piece will always be primarily a piece for violin. This is never the case as soon as microphones and loudspeakers reproduce a sound.

teapot. Of course, this is physically impossible, but even if it were possible, a piano that small could never produce such extended resonances. The total sound would be very different from what the loudspeaker reproduces in the piece. The *reproducing* approach makes it possible to produce a sound with a membrane which would otherwise never have been able to resonate within the teapot. In *Nothing Is Real* there are two different semantic sources for the sound acting simultaneously: the playback of the resonating chords of the piano, and the irregular resonating glissandi produced with the help of a teapot lid. Microphones and loudspeakers are capable of communicating these semantic sources simultaneously, since they do not have only a single semantic sound source, as other musical instruments do.

How is it possible to distinguish between these two semantic sound sources when they occur in one musical set-up, as is the case in *Nothing Is Real*? To answer this question I examine a feature I consider to be crucial for the discrimination between sound sources, the so-called musical gesture.

Musical gestures and gestural identities

As long as music could not be "reproduced", the identification of a sound source was of no importance. The musicians were always present, and all sound production technologies used could usually be visually verified (Emmerson 2007, 4). In sound reproduction technology the semantic source is not the same as the device used to generate the sound. For this reason, it was soon recognised that being able to identify the semantic source becomes critical for the success of sound reproduction devices. Musical instruments are built for producing a specific sound, whereas sound reproduction technology is constructed to reproduce all sounds. The sound itself does not *per se* help to identify the physical source when this source is a sound reproduction device. The actual physical source, the phonograph in the Edison tone tests, is ignored by the audience, and only the semantic source is heard. But in some musical performances, such as *Nothing Is Real*, both sources—piano and loudspeaker—seem to be present at the same time.

One of the reasons discrimination between different types of sound sources, such as a violin or a piano, has to do with the recognition of the gesture of the sound. What is such a gesture exactly? It could be described in many different ways. Very often, gestures are defined as being related to both the body and the mind, and the most efficient description of what a gesture is seems to be movements of the body with a meaning (Jensenius et al. 2009, 12–13). What makes matters more complicated is that the expression "musical gestures" is often used not only for movements made by the performer but also for so-called gestures in the music itself. Such gestures, like for example, a motive in a Beethoven symphony, are contained within the tonal, rhythmic or timbral scoring of the work, and do not necessarily need to be realised by the movements of a performer.

A musical gesture could therefore be defined more specifically by "an action pattern that produces music, is encoded in music, or is made in response to music" (Jensenius et al. 2009, 19). For my research I will mainly consider gestures which produce and are encoded in music.

In *Nothing Is Real*, there are at least two types of gestures in play: the action pattern of the piano playing and that of the teapot lid movements. For the piano playing to be recognisable, as was the case with the Edison phonograph, no perfect high fidelity recording is needed. Even in the worst conditions, such as through a telephone loudspeaker or through very low quality headphones, the piano will still be recognised quite easily by an experienced audience (that is, an audience that knows what a piano sounds like). What is listened for in this case is not whether the whole sound spectrum is transmitted by the loudspeaker or how much distortion there is in the frequency response, but the recognition of a specific action pattern. Michel Chion* argues that as soon as an audience is listening to recorded sound without being able to see the source of that sound, listeners will often search even harder for the semantic source of that sound in order to identify it (Chion 1994, 32). The gestures audible in the sound, in this case the gestures of piano playing, help to identify the semantic source. The blurred quality of the recording in *Nothing Is Real* might even intensify the effect of the *reproducing* approach, since the listener has to make some effort to recognise the piano. If this would be a spotlessly clean recording, in a living room ambience or in concert, the piano would be taken for granted. But this small loudspeaker in the teapot forces the listener to search for the piano in the sound. The *reproducing* aspect is perhaps even emphasised as a result of the "bad" quality recording.

But how are the differences between the piano recording and the effects of the movements of the teapot lid recognised in this performance? Before the use of electricity, instrumental playing was a process in which the corporal condition of the performer was made audible. Whereas the bodily movements of string and wind performers exert a great influence on the sound of their instruments since constant contact is required to produce it, this influence is much smaller in the case of the piano or of percussion instruments, since only the beginning of the sound can be influenced (Craenen 2011, 143). Sounds requiring a lot of contact with the body of the performer will, for example, sound more "alive" than sounds that can only be attacked. Paul Craenen* calls the specific characteristics of these movement and instrument relationships the "gestural identity" (Craenen 2011, 162) of the instrument, as a result of which a certain action will result in a certain kind of sound development (Craenen 2011, 159).

The one sound-producing object in *Nothing Is Real*, consisting of a loudspeaker in a teapot, is perceived as containing two different types of musical gestures, referring to two different gestural identities: that of the piano recording and that of the teapot lid movement.The piano recording playback is modified by the teapot lid, and during the performance the listener might oscillate between recognising the piano recording and the modifications created by the teapot lid movements. Referring to the several kind of gestures in music I mentioned earlier, the piano recording consists of sounds containing information concerning gestures *encoded* in music, and the teapot lid movements *produce* modifications to this music.

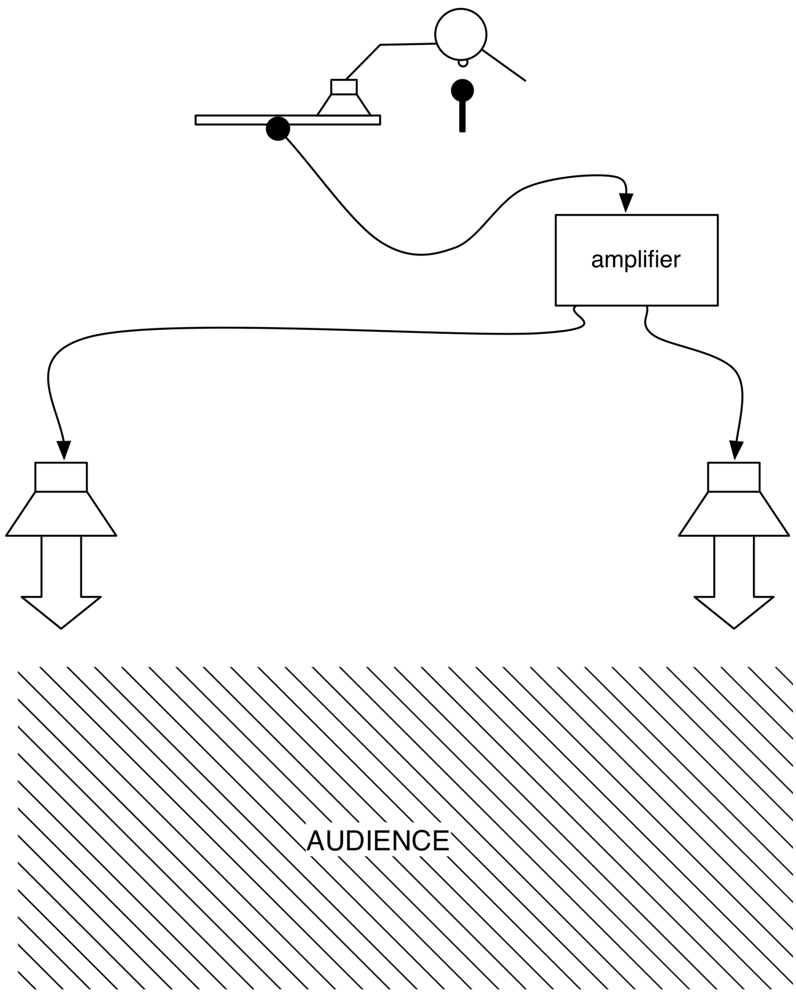
As I will explain with the help of some further musical examples, the combination of several of these gestural identities can lead to interesting starting points for compositions and performances. The several identities do not need to exist next to each other in the same piece, as in *Nothing Is Real*, but one gestural identity can also be transformed into another one. These so-called "gestural identity shifts" play a major role in the piece *Windy Gong* by Ute Wassermann*.

Gestural identity shifts: combining the supporting and interacting approach: *Windy Gong* by Ute Wassermann

In *Windy Gong* Wassermann sings through a microphone and holds a small loudspeaker in her hand through which her voice is amplified. A very thin gong is placed next to her and, while holding the small loudspeaker in her hand, she can touch the gong gently with the vibrating loudspeaker.[83] The gong is brought into vibration by the vibrations of the loudspeaker. A contact microphone attached to the gong amplifies the gong vibrations through two loudspeakers (see scheme *Windy Gong*).

The possibilities of playing the gong with the small loudspeaker differ significantly from normal gong playing, for the most part done with a mallet. The vibrations of the loudspeaker should be seen as very small, fast and soft strokes on the gong. Since these vibrational strokes are as fast as the frequencies that Wassermann is singing, the sound result differs greatly from that of normal gong playing. As long as Wassermann does not touch the gong, the sound coming through the loudspeaker is barely audible for the audience. As soon as the loudspeaker touches the gong, it causes the gong to vibrate. The gong reacts in very differentiated ways to the sounds made by Wassermann, similar to the loudspeaker sculptures in Tudor's *Rainforest*. The gong is *interacting* with the loudspeaker. Whereas small noisy sounds, like whispers, generate considerable resonance in the gong, other more pitch-oriented sounds might trigger much less response, owing to the response tendencies of the gong towards certain frequencies of an inharmonic

[83] A cork is attached to the dust cap of this small loudspeaker to facilitate contact with the gong, since loudspeaker diaphragms are in general concave.



Ute Wassermann *Windy Gong*: the voice of the performer is picked up by a microphone and amplified through a small loudspeaker. This loudspeaker is used by the performer to bring the gong in vibration. The gong itself is amplified with the help of a contact microphone and two loudspeakers.

spectrum[84] (unless the pitch-oriented sounds are at the same frequency of one of the resonant frequencies of the gong, which will result in a much stronger response of the gong). When the gong resonates as a result of the loudspeaker vibrations, these vibrations are in a way "playing" the gong. When the gong resonates less, the singing voice becomes the main point of focus. The voice is approached in a *supporting* way by microphone and loudspeaker. There are therefore two gestural identities in this performance: the singing voice amplified through the loudspeaker and the gong played by the singing voice (through the vibrations of the loudspeaker). The

[84] A harmonic spectrum is a spectrum which partials are all whole number multiples of the fundamental frequency. As soon as there is any deviation of this a spectrum is called inharmonic. The sounds of instruments like gongs and bells are inharmonic spectra. When a harmonic spectrum, like a singing voice, is used to "play" a gong, as is the case in the performance of Wassermann, there won't be much frequencies in this harmonic spectrum that are also present in the inharmonic spectrum of the gong. Noisier sounds will have an inharmonic spectrum containing many different partials and this spectrum will therefore share much more frequencies with the gong spectrum.

difference between Wassermann's performance of *Windy Gong* (1995) and *Nothing Is Real* by Lucier, is that transitions can be made from one of these gestural identities to the other. With the sounds of her voice, Wassermann controls response levels of the gong, and she can control whether the small loudspeaker is touching the gong or not. There are two main gestural identities during the performance–the gong played by the loudspeaker and the voice sounds produced by Wassermann–but the majority of sounds emerge from somewhere in between these two identities, and constant transitions are made from one to the other. These are what I would like to call *gestural identity shifts*: the amplified voice transforms into the resonating gong or vice versa (listen to the audio example *Windy Gong*).

Ute Wassermann and the set-up as used for *Windy Gong* (performing the piece *Fausse Voix* (2006), written for the same set-up).

The question might arise as to why this voice modification could not be controlled by a simple MIDI pedal or fader, and executed by some live electronic processing of the voice by a computer. By holding the loudspeaker that reproduces the sound of her voice in her own hand, Wassermann can control the sound modification more directly and react more quickly to the response of the gong than with a fader or pedal that modifies the sound of her voice. She is in actual contact with the gong, whereas with a fader or pedal, there exists an interface in between her and electronic sound processing. As she mentions herself, the reaction of the gong changes with every performance space, and there is always a danger of feedback (Wassermann 2006, no page numbers). Flexible control of the loudspeaker-gong contact is essential as well as that all her movements are traceable for the audience. In contrary to a process supported by computer-software, during which, at least for the audience, everything might be assumed possible, there are clear limits to this set-up. Wassermann takes one element from an electronic performance practice, namely the use of loudspeaker amplification, and combines this with elements of acoustical performance practice, such as physical interaction between the gong and the loudspeaker vibrations. In live processing all this would of course occur with the processing of an electrical signal or a digital code. Doubtless the sound of the performance would also be different if the processing were rendered by computer software instead of through this physical set-up. *Windy Gong* could also not be performed by means of conventional performance practices, since the gong could never be played by a human in the way that it is played by the loudspeaker. The microphone and loudspeaker are crucial elements in the interactions between the electronic and mechanical aspects of this performance.

In performances with the *Windy Gong*, the gestural identity shifts are largely controlled by a performer who decides which of the applications of microphones and loudspeakers should be more audible (the physical generation of gong resonances or the amplification of voice sounds). However, these gestural identity shifts can be composed without taking a performer into account. In the next performance, the set-up consists of a loudspeaker sculpture that is not played by any performer. Nonetheless, the performance clearly contains gestural identity shifts, but this time, however, only through gestures *encoded* in music in combination with the visual aspects of the sculpture.

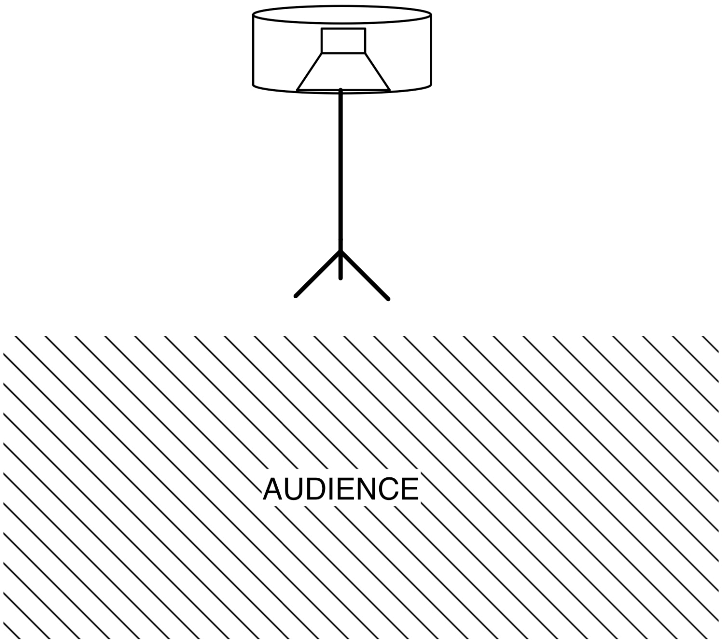
Gestural identity shifts through sound only: snare drum pieces by Wolfgang Heiniger

Many pieces by Wolfgang Heiniger* could be analysed as compositions with several gestural identities which exist without any performer movements occuring on stage. Heiniger makes use of snare drums each equipped with a loudspeaker hidden inside (see the scheme of the snare drum).[85] The first conspicuous aspect experience in these pieces is the absence of a performer for the snare drums. They appear alone on stage, sometimes in combination with other instruments and their players, such as a saxophone or string quartet, occasionally only with other snare drums, but never with their common companion, a percussionist. For this reason, Heiniger calls them "self-playing" drums, which sound despite the absence of a player, though not in the idiom of a solo snare drum. Sometimes they produce a sound reminiscent of an electronic organ, sometimes a plethora of wild noises and then suddenly the well-known sound of a snare drum itself. These sounds are generated through vibrations emitted by the loudspeaker inside the drum, which causes the snare drum to resonate by means of a process similar to that applied by Tudor as well as Wassermann. These highly varying sounds are all coloured by the same kind of resonator, namely the snare drum. Two different relations between the air pressure waves generated by the loudspeaker and the snare drum are used. There are sounds produced by the loudspeaker which cause the snares and the drum to vibrate as well, and therefore to produce sound as well. Inaudible sounds are played through the loudspeaker as well though. These are in general very low frequencies, that are not detectable by the ear but will cause a big air pressure wave to move towards the drum's membrane and snares. The loudspeaker is thus "hitting" the snare drum, producing movement by low air pressure waves, but without producing any sound itself.

The difference with Tudor's *Rainforest*, is that in this case the resonator's sound is already familiar. For this reason the question "how does this object want to sound", so important in *Rainforest*, is not so relevant here. In *Windy Gong* both gestural identities—the voice and the gong—are known sound sources. The sonic outcomes of the snare drum pieces of Heiniger may be placed between those of Tudor and Wassermann: the sound of the snare drum is well-known (as are those of the sound objects used in Wassermann's performance), while the sounds coming from the loudspeaker are unpredictable (similar to those emitted in Tudor's *Rainforest*).

Since the audience is familiar with the sound of a snare drum, the visual image of the instrument in itself already summons up strong sonic associations and expectations. In Heiniger's pieces the loudspeaker seems to be in a certain way as passive as those in our living room. It achieves a transformation simply through the fact that it is hidden in a snare drum, which transfigures not

[85] Pieces written for snare drums containing loudspeakers by Wolfgang Heiniger:
- *LAMENTO III* (2003) for contrabass saxophone, percussion, two self-playing snare drums and electric motor.
- *LAMENTO V* (2003/04) for string quartet and self-playing snare drum.
- *Engelszungen* (LAMENTO IX) (2004) for ensemble and two self-playing snare drums.
- *Desafinado* (2005) for soprano saxophone, self-playing snare drum and loudspeakers.
- *5 Türme in flacher Landschaft* (2007) for seven self-playing snare drums.
- *SCHWINGKREIS* (2010) for snare drum and two self-playing snare drums.
- *FLATSCAPE* (2010) for ten self-playing snare drums.



Wolfgang Heiniger, snare drum: a loudspeaker is placed inside a snare drum, so the sound emitted by the loudspeaker will cause the drum to resonate

only its visual identity but also its audible characteristics. Although the set-up remains exactly the same, the sounds played through the loudspeaker engender gestural identity shifts. If only drum sounds were generated by the loudspeaker inside this snare drum, the set-up would, in terms of output, not differ greatly from a drum-playing musical automaton. In contrast to a musical automaton, however, through the use of the loudspeaker as an exciter for the snare drum, all kinds of sounds become available to the composer. The sounds used to excite the snare drum are not produced on stage; the loudspeaker in the snare drum receives its audio signal from a computer. Due to the fact that the sounds are *generated* by the computer, there is no longer a single gestural identity for the sounds produced by the loudspeaker, as was the case with the piano recording in Lucier's *Nothing Is Real* and the voice amplification in Wassermann's *Windy Gong*. When the sound diffused by the loudspeaker sounds like a snare drum, the gestural identity will be a snare drum, but as soon as the loudspeaker emits sound through the *generating* approach, all kinds of gestural identities, including morphed, hybrid and indefinable ones, are able to come into being. Although within the *generating* approach any reference to sound origins is avoided, this does not mean that no musical gestures are encoded in that music.

Fünf Türme in flacher Landschaft (2007) for seven self-playing snare drums by Wolfgang Heiniger.

Musical gestures can also be present in acousmatic and electronic music, which now refer not to human action, but to artificial action patterns created by the composer, consisting, for example, of an increase in energy in the sound, followed by a release. They could be seen as musical gestures made by the composer him- or herself (Windsor 2011, 58–60).

Combining the generating and interacting approach

In the case of Heiniger's snare drum pieces, the musical gestures have all been encoded into the music, and, owing to the interaction between these musical gestures and the resonances of the snare drum, the sound may be associated with many different gestures. The identity of the snare drum changes depending on the sounds played through the drum: the electronic sounds reveal unexpected sounds latent in the snare drum, whereas the drum sounds fall in line with normal expectations and confirm the sound identity of the snare drum. The two approaches combined here are the *generating* and the *interacting* approach. As soon as typical drum sounds are heard, and the snares of the drum are excited by these sounds, the listener experiences the drum as being "played" as if using a drum stick. A clear theatrical aspect enters the performance here, since every stroke of the drum sound reminds one of the absent player. The perception of an instrument being played is accomplished by the sound itself, not through any movement of the player, as was the case in the pieces by Lucier and Wassermann. The characteristics of this sound in combination with the visual associations of the snare drum give rise to an association with an instrument.

These self-playing drums reveal another area of potential in composing for loudspeakers: the musical gesture *encoded* in the sound itself in combination with a clearly identifiable resonator can engender many sound identities. Usually a sound serves to identify the object that has produced the sound. It is easy to recognise if an instrument has been bowed, blown or struck and whether the material is wood or metal. The sound itself often also reveals if, for example, the degree of force with which a string is bowed and where it is bowed. But in Heiniger's snare drum pieces, the sounds which seem to be produced by the object, can also produce characteristics that do not belong to it. The bizarre and unexpected sounds of the drum put into question the musical instrument's identity, which at first seemed to be so fixed (listen to the audio example *Desafinado*).

Composed relationships between body movements and resulting sound

In Heiniger's pieces, the relationship between the sound-producing objects and the sound itself is constantly changing, and the compositional plan can be regarded as a development of these shifts from one relationship to another. Sounds are combined with an object (namely the snare drum) with which they would never be connected in "reality". The snare drum is enabled to produce sounds that it would never produce without the intervention of the vibrations produced by a loudspeaker. At the same time, the sounds radiated by the loudspeaker would sound significantly different without the resonance of the snare drum. As I demonstrate in the last part of this chapter, these relationships can be developed further. This results in musical works in which relationships between performer, instrument and sound can be composed, instead of being solely dependent on mechanical laws. What is distinctive when working with loudspeakers is that these relationships depend not only on mechanical laws, as is the case with acoustic instruments, but also on relationships between gestures and sound which have been created with the help of electricity.

Analysing instrumental playing without the use of any electricity, one could say that intentional movements by a performer are transformed into vibrations of an object, which are perceptible as sound to human beings. These direct relationships between movements, body, vibrations and materiality were valid for the production of music until the invention of technologies for sound recording and sound reproduction, and could be dismantled as soon as it was possible to transmit sound through space or time. I would like to emphasise that it is only sound that is transformed or stored by sound reproduction technology, since the other elements of a musical performance, such as the movements of the performer or the appearance of the instrument, are not stored on a recording. As my description of the *Konzertreform* in chapter 1 revealed, all other parameters of a musical performance were regarded by many at the beginning of the twentieth century as superfluous to music. It is exactly this establishment of sound as the sole component of music which greatly influenced, and reconstructed, the relationships between movement and sound.

The loss of the direct relationship between the moving body of the performer and the vibrating material of the instrument, or, in other words, between what is heard and what is seen, may be thought of an opportunity to compose these relationships anew. Such relationships are an inevitable consequence of the laws of classical mechanics, as long as no electro-acoustic sound reproduction is involved. By working with sound waves which are transduced into electricity, and electricity transduced into sound waves, these relationships become totally arbitrary and open to any kind of connection between gestures and resultant sound (Miranda and Wanderley 2006, 2–4). A very soft sound in front of a microphone could cause a very loud sound to be emitted by the loudspeaker, or vice versa. The reaction of an electric instrument no longer depends on the laws of classical mechanics, but is dependent on the way the several parameters of the resulting sound are connected to the incoming signal. When microphones and loudspeakers are the main focus of compositional strategies, the potential of both these worlds, mechanical and electrical, become available to the composer. This implies, as the examples above demonstrate, that inherent relationships between performer and instruments can be combined with composed relationships. In the case of composed relationships, the decision as to which movement causes what kind of sound is no longer determined by the laws of classical mechanics, but may be designed by the musician herself. Performer movements and their relationships to the resulting sound can, as soon as these relationships are composed, also shift from one gestural identity to another. And even without the physical presence of a performer, gestural identity shifts can take place in a performance. In Heiniger's set-up, these identity shifts are present only in the sound, but the visual aspect of the snare drum as well as the absence of a performer are essential for the realisation of these gestural identity shifts. Owing to the absence of the physical generator of the sound, different associations can be made in relation to the semantic sound source.

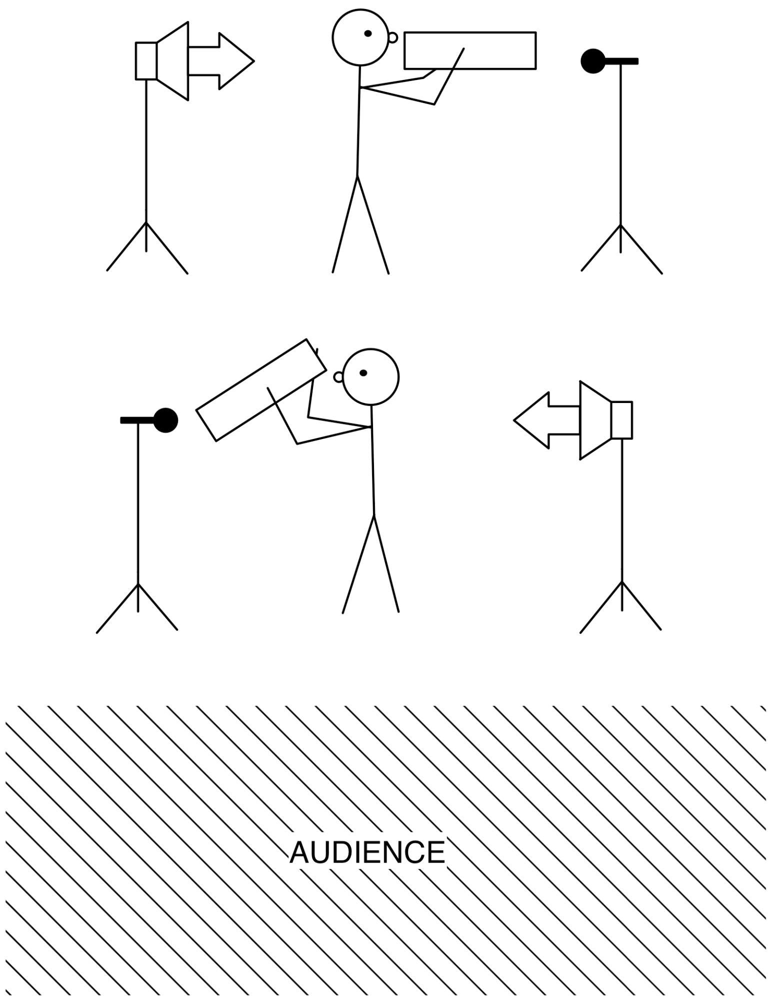
Performers changing their identity: *tubes* by Paul Craenen

Paul Craenen argues that as soon as a musician produces sound with a new or unique set-up, as is the case with all the examples I have mentioned in this and the previous chapter, then this set-up itself becomes a focal point, drawing attenton to the "how and what of sounding" (Craenen 2011, 186). Craenen calls this a new compositional parameter, since the situational aspect of sound production becomes part of the compositional process. The instrument becomes an essential part of the composition itself, instead of being a well-known device which merely translates the performer's expression. These new set-ups might call for unknown or unexpected gestures in sound production. An example is the teapot lid movement in Lucier's *Nothing Is Real* (as far as I know, no other composition exists in which the position of a teapot lid is an important parameter), as well as many of the movements used by the performers in the pieces examined in the previous chapter. During the performance *tubes* (2007) by Craenen himself, the kinds of movements he uses are not only novel to musical performance, but the manner of these movements also changes during the performance. According to Craenen:

> During the creation process of *tubes*, special attention was paid to the status of the performing bodies [...]. The performer's identity oscillates between the identity of a dancer executing choreographic movements in a disciplined way, the identity of a musician playing the tubes in a close interaction with what he/she hears, and the identity of a technician testing out sound possibilities and constructing a feedback instrument (Craenen 2008, no page numbers).

In this performance, two microphones and two loudspeakers are used, facing each other in a rectangle on stage (see scheme *tubes*). The principal sound is, once again, acoustic feedback. All changes in sound in the piece are triggered by the performers, who place grey PVC tubes (normally used as drainpipes) in front of a loudspeaker or a microphone. These tubes resonate the sound waves produced by the loudspeaker and—analogously to the relationship between the length of a flute and its pitch—force the feedback towards a frequency which is inversely proportional to the length of the tube, in the course of which the overall amplitude will also increase owing to the increased resonance of the sound.

However, as soon as the performance starts, it becomes clear, that there is more going on than just manipulation of the sound through altering the acoustic conditions of the set-up by means of the tubes. Many more aspects of the sound change as soon as tubes are placed in front of a loudspeaker or a microphone. In between the microphone input and the loudspeaker output is computer software, which processes the incoming sound according to the amplitude of the microphone signal. Each time the volume of the sound increases, a border is crossed in the software, and a new preset is activated. As soon as the volume decreases again, the preset switches back to the preset belonging to this lower volume level. There are five levels of software preset changes, the fifth level being reached when a tube is placed in such a way that microphone and loudspeaker are directly connected to each other, therefore producing the loudest possible feedback levels for this set-up. Each level is processed live in a different way,



Paul Craenen *tubes*: acoustic feedback between two microphones and loudspeakers is manipulated by two performers with the help of pvc pipes. The microphone input is processed by a computer software, depending on the amplitude of the microphone signal.

applying techniques such as pitch shifting and granular synthesis to produce short melodies, clear pitches, fuzzy noises or rapid glissandi, depending on which software level is active.

The audible result is in part related to the acoustical laws of the physical world: larger objects (larger PVC tubes in this case) result, for example, in a louder and lower sound. The combination of tubes, their distance from the microphone, and the possibility of changing the acoustic characteristics of the tubes by closing one end with a hand, result in endless possibilities for playing this feedback system, and all these changes are immediately perceptible in the resultant sound. The performers are *producing* music with their gestures, and the performers are *interacting* with microphones and loudspeakers. At the same time, the electronic processing creates an additional alteration of these sounds, for example small melodies, not played by the performers but generated by the computer software with the acoustic feedback audio input, which contain their own kind of gestures, *encoded* in the music. This aspect of the sound production is no longer related to acoustical laws but only to digital sound processing, and is therefore clearly an example of the *generating* approach: the acoustic feedback sound is used as

Paul Craenen and Cathy van Eck performing *tubes*.

input for a variety of sound processing which is not related to the gestures of the performers, but which instead generates its own musical gestures.

In this work the performers themselves change their identity —dancer, musician and technician are the words Craenen uses to describe their roles. There are choreographic parts during which, with the help of short tubes, high-pitched feedback sounds are produced by the "dancers". At other moments in the performance, an installation is built by "technicians", with many connections between the microphones and loudspeakers. The computer software now *generates* a low and fast-moving sound structure. The musical identity of the performers, the third identity, is created through the direct *interaction* between the performers, the tubes and the loudspeakers. The performers "play" the set-up as if it were a musical instrument (see the three video examples of dancer, musician and technician in *tubes*).

Considering the possibilities of playing an electronic instrument, one of the main focal points of research is the problem of its playability. Electronic sounds, whose only point of connectivity to the resulting sound often seems to be a "turn on turn off" button, do sound unmediated in comparison with conventional musical instruments (Wishart 1996, 180). Obviously, with electronic music, it is not easy to achieve the degree of control commonly experienced with conventional instruments, since the relation between movement and sound is no longer the inevitable result of the mechanics of the instrument. The control of the electronic sounds needs to take place "intuitively" (see for example (Knapp and Cook 2005)), which can be complicated since any physical action of the performer can result in a completely unpredictable sound output. In a non-electronic environment, the relationship between body and sound could be called "predictable", but as soon as electricity is used in music this predictability is lost.

Whereas many efforts have been made to obtain a kind of direct control in electronic music (Knapp and Cook 2005), I find that it is exactly the separation between the category of gestures used to *produce* music and the category of gestures *encoded* in music which can be fruitful for experimentation and creativity (see the explanation of the different categories of musical gestures on page 84). An example may be found in *tubes*: the "technician identity" is realised through a gesture by the performers that might be described as essentially "putting an object in the right place", which is in fact an act similar to an on/off button of a controller for electronic music. The audible result is unrelated to the corporeal actions of the performer. Whereas this might be experienced as a negative aspect according to conventional musical instrument design, I feel that it is very valuable for this particular performance. If the instrument were a transparent musical interface, shifts in gestural identity such as those happening in Craenen's piece would not be possible. Idiosyncratic relationships between a performer's gesture and the resulting sound may be constructed, and changes in these relationships composed into the formal structure of the musical work.

Open musical instruments

The development of most musical instruments has been one of trial and error, often until a form was found which was considered to be "finished" by the musicians playing these instruments and/or by the instrument-makers. Most traditional instruments, such as pianos and violins, have found a form that seems to be accepted by musicians as their—at least during the last century—final form. Many of the examples discussed in this and the previous chapter, however, incorporate instruments which could not be described as finished, remaining rather in an experimental state, in which they only partly function, their reaction is very precarious or they are easily modified into something else. Instead of being highly sophisticated objects which can be controlled by experienced musicians with a high level of precision, these set-ups seem to be the opposite: they are not highly controllable, and the musician plays a different role from that of "mastering" the instrument. Such absent and unfinished aspects of the pieces keep the relationship between performer, object and sound in constant motion and create the possibility of composing with these relationships, as analysed above.

These unfinished instruments could be called "open musical instruments". Dick Raaijmakers* describes conventional musical instruments as being "closed". Although they can be opened, for cleaning them, repair or tuning, they only become playable when they are closed again (Raaijmakers 1989, 9). Raaijmakers mentions that at the end of the nineteenth century most instruments were used in closed form, and could be called a purely technical product which was "finished". During the second half of the twentieth century, a development took place in which many instruments were "opened",[86] as Raaijmakers calls this process, by musicians, evolving into forms varying from "work of art" to "work in progress" (Raaijmakers 1989, 12–13). Raaijmakers curated an exhibition for the musical instrument department of the Haags Gemeentemuseum which included numerous"open" musical instruments. All works in this exhibition consist of conventional instruments, such as pianos and violins, which have, in some way, been "opened" by artists. One of the exhibits was the tam-tam set-up for *Mikrophonie I* by Karlheinz Stockhausen*, as described in chapter 4.

Not only Stockhausen's tam-tam, but also Ute Wassermann's gong and Wolfgang Heiniger's snare drum) could be described as "open instruments". But, while pieces with drainpipes (Paul Craenen), weird sculptures (David Tudor), a tea pot (Alvin Lucier) or simply microphones and loudspeakers (Hugh Davies) are not related to any conventional musical instrument at all, I still

[86] I decided to employ the term "opened", since this is how Raaijmakers calls the act of altering, transforming or even destroying conventional musical instruments (Raaijmakers 1989, 11).

consider these set-ups as "open musical instruments". This term as defined by Raaijmakers, is used to indicate closed instruments which have been opened by an artist. The second category mentioned above refers to open instruments which have not yet reached a closed state, which of course they do not actually need to reach. Whereas in the first category the reference to music is obvious, considering the object itself (given that pianos or gongs are, in our culture, associated with musical performance), in the second category it is the actual set-up that makes the instrument "open". Craenen uses this feature to create several identities: PVC tubes are not associated with music in the first place, but can become (a part of) a musical instrument as a result of the actions of musicians who treat them as such in the course of the piece. In Craenen's performance, the form of the open musical instrument is in constant fluctuation, being built, taken apart, or rebuilt in another form by the performers.

The reproducing approach controls the interaction: *Open Air Bach* by Lara Stanic

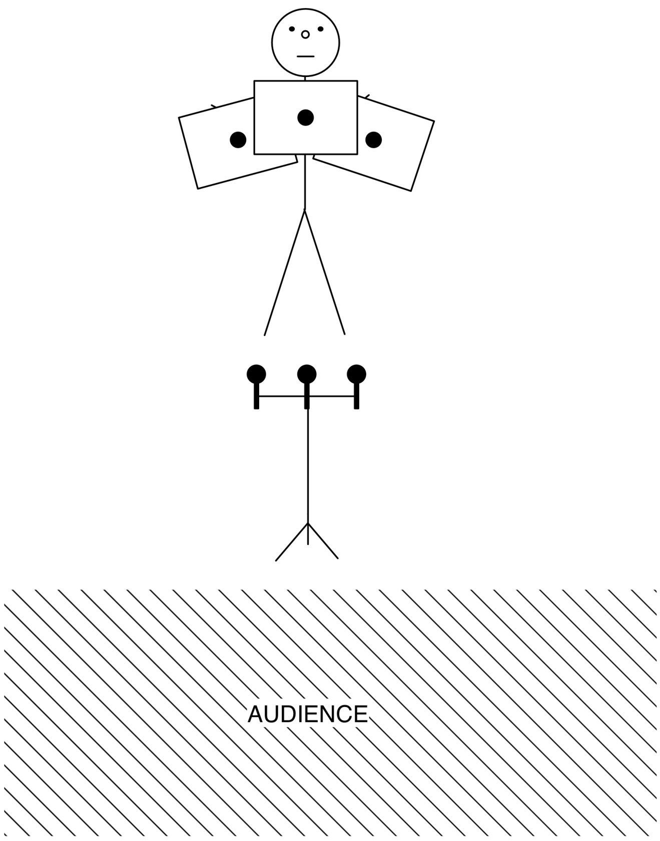
The last performance I will examine is *Open Air Bach* (2005) by Lara Stanic*. Although visually quite different, the performance set-up for Stanic's performance is technically similar to that of Hugh Davies for his *Quintet*, and uses the distance between microphone and loudspeaker to control the parameters of the performance. Unlike Davies, Stanic does not work with acoustic feedback sounds, but uses the amplitude of the sound waves picked up by the microphone to control several parameters of the output of the loudspeaker. This is what might be called "data feedback". The amplitude of the microphone input, and not the sound waves oscillating between microphone and loudspeaker, controls the sound processing in the computer. The resulting sound is emitted by the loudspeakers and once again picked up by the microphone.

For this performance, three very small loudspeakers without a diaphragm are each attached to a sheet of paper which itself functions as a diaphragm.[87] These paper-loudspeakers are attached to the performer's body (one on each arm and one on her chest) as she walks towards a stand on which three microphones are attached. A soft sound is heard from the loudspeakers. During her walk towards the stands the sound becomes louder and louder, the playback speeds up, and instruments, melodies and harmonies become recognisable. A piece by Bach is heard, in a very unstable version, with pitch and speed of the piece in constant fluctuation (see scheme *Open Air Bach*).

What is happening here? In Stanic's performance, the sound produced is not acoustic feedback, but the three parts (flute, violoncello and cembalo) of the E-minor Sonata of Johann Sebastian

[87] These loudspeakers are piezo ceramic, they can also be used as contact microphones. See the appendix on microphone and loudspeaker technology for more information.

Bach are each projected through one of the three small loudspeakers. The playback speed of the sonata depends on the volume level of the microphone input. At the beginning there is the largest distance between Stanic and the microphones, so the playback speed is very slow, resulting in a very low and slow performance of the sonata. As soon as she approaches the microphones, the sound becomes higher and faster. As Stanic herself phrases it, the task of the performer is to bring these three instrumental parts towards the right pitch and playback speed, so that the Bach sonata is reproduced as accurately as possible.[88] This is no simple task, since fluctuations in volume will change the speed again as soon as an optimum position is found.



Lara Stanic *Open Air Bach*: The performer has three small loudspeakers attached to her body. Through each of the three small loudspeakers a sound file is played. Depending on the amplitude of the input signal of three microphones, the sound files are played faster or slower. The closer the performer gets to the microphones, the faster the sound file is played.

[88] As soon as Stanic reaches the right playback speed, several pieces of papers attached to the microphone stand start rotate. Since this aspect of the performance is not important for my analysis of Stanic's use of microphones and loudspeakers, I will not address this..

During the performance, she continually searches for a new position at which the piece can sound at the correct speed. Also, whereas a certain movement might bring one of the three loudspeakers closer to the microphone, it will simultaneously change the distances between the other two microphones and loudspeakers. Stanic is not playing the Bach piece, but the Bach piece is playing her, so to speak, and "forces" her to make certain movements to accomplish her task. The movements during the performance reveal a constant searching for control of the sound by the performer, a control that will never be achieved (watch video example *Open Air Bach*).

With this work, the *reproducing* approach is put to use as a kind of score for the performer's movements, resulting in gestures of the performer that look stiff, unnatural and as if the performer is being coerced into making them. They are clearly not the articulated gestures of a musician who is "in control". Stanic's gestures contrast greatly with the musical gestures suggested by the playback of the Bach sonata: the gestures *encoded* in music (which will be, at least partially, heard by the audience of *Open Air Bach*), as well as the gestures that *produce* music (which can only be imagined by the audience), are fluent and expressed in a comprehensible way. An audience familiar with the music of Bach can mentally reconstruct these gestures, even despite the extensive deformations caused by the speed changes. Additionally, Stanic is a flute player herself, who thus knows the music-producing gestures of this piece very well. Her movements contrast greatly with the original movements of the flute player. The two gestural identities here do arise from the warped playback of the Bach piece. On one hand, every gesture seems to be shaped smoothly, while on the other, the gestures of the performer, trying to achieve a correct rendition of the Bach sonata, involves unusual, awkward gestures that seem to have no relation to it, or indeed to music in general. The *reproducing* approach (the Bach piece as it should "normally" sound) controls the *interaction* between performer, and microphones and loudspeakers. The performer is physically searching in this piece to bring the microphone and loudspeaker back to their identity as transparent musical channels.

Resistances and resonances of microphones and loudspeakers

I started my research with the question in mind whether microphones and loudspeakers are musical instruments. In chapter 2, I analysed four different approaches—*reproducing*, *supporting*, *generating* and *interacting*—towards microphones and loudspeakers in the context of musical instruments. The *interacting* approach is how a performer normally approaches a musical instrument and it seemed therefore reasonable to me that this would be the appropriate way to approach microphones and loudspeakers. As I discussed in chapter 2, this *interacting* relationship between musicians and their instruments is formed by so-called resonances and resistances. To discover the resonances and resistances of microphones and loudspeakers, I

Lara Stanic performs *Open Air Bach*.

investigated, first of all, what would be a "genuine" sound shaped by microphones and loudspeakers. I concluded at the beginning of chapter 3 that acoustic feedback is this sound. During the rest of this chapter I analysed how microphones and loudspeakers became devices that should *receive* or *emit* but not *shape* sound.

Nonetheless many composers working with microphones and loudspeakers during the 1950s and 1960s tried to bring them back to *shaping* the sound and therefore into the realm of musical instruments. Composers such as Davies, Stockhausen, Tudor, Bayle, and Nono, whose work I analysed in chapter 4, explicitly mention this as their aim. For this examination, I defined three compositional parameters of interaction between performers, microphones and loudspeakers, and other elements of the performance: *movement*, *material* and *space*. These three parameters are derived from conventional musical instrument playing. I came to the conclusion that not only the use of acoustic feedback (which I called a *circle of* feedback*)* makes it possible to *interact* with microphones and loudspeakers, but that this is as well the case with set-ups that are a *line of amplification* or a *point of radiation*. Also, the analysis of these pieces revealed that microphones and loudspeakers might be used in a manner similar to musical instruments in these pieces, but at the same time, the functions of the performers, conventional instruments or audience also altered. Through the efforts to transform microphones and loudspeakers into real instruments, it fairly quickly became obvious that microphones and loudspeakers belong to the realm of sound producers (as musical instruments are defined by Hornbostel, see chapter 2), but do have their own characteristics, which leads to a music practice differing from the one dealing with conventional instruments. As I evaluated at the beginning of chapter 5, many of the works discussed in chapter 4 use a combination of my approaches. By using the *interacting* approach microphones and loudspeakers become perceivable as sound shapers. By using one or more of the other approaches, the unique features of microphones and loudspeakers are revealed.

With the use of electricity, resistances and resonances of a set-up can change during the performance. Not possible with acoustic instruments, the same movement can result in a different sound. At the same time, the physical component of microphones and loudspeakers also brings in some specific resonances and resistances that cannot be composed due to their dependence on laws of classical mechanics. No longer interested in a perfectly functioning instrument, many artists create unstable set-ups that are in constant motion. The resistance and resonance therefore often fluctuate in their performances. Compositions become a discovery of the possibilities of connections between the sight and sound of the set-up itself and, therefore, of the several potential identities of the set-up.

In many of the more recent works I discussed, especially the works by Wassermann, Heiniger, Craenen and Stanic in chapter 5, the artists *interact* with microphone and loudspeaker, but not with the aim of using them in a way similar to a conventional musical instrument. They seem to be interested in these devices especially due to the characteristics that distinguish them from conventional instruments. Taking Stanic's performance as an example, it is clear that if she was able to reproduce the Bach performance easily and perfectly, her performance would not make much sense anymore. The task of accomplishing an accurate playback of the Bach recording is impossible, since the set-up does not permit this. The performance is not about the virtuosity of the musician or the perfect interpretation of a score. Stanic is disposed to a constant struggle to achieve the impossible; and owing to the recognisability of the Bach piece, the audience knows exactly what she is struggling for. This is completely different from what is the case in many compositions for conventional instruments, when the performer rehearses the piece well and the audience will have the impression that the performer thus "masters" the composition on her instrument, when she performs in public. The works created by artists working with microphones and loudspeakers, as described in this chapter, lead to the necessity of composing the relationships between performer, movements and sounding results. Various relationships between what is audible and what is visible develop during the pieces.

Since we do not connect a very specific sound with microphones or loudspeakers, as would be the case with conventional instruments, their identity depends on the context. This context is formed by playing them and therefore creating or strengthen an identity. By using the unique characteristics of microphones and loudspeakers as sound producers other aspects of composition can come into focus that differ from composing for acoustic instruments: a composition can focus on identity shifts of the sounding objects themselves, since the instrument does not have an identity as rigid as the piano or violin. As the many examples in this thesis have proven, the microphone-loudspeaker instrument is flexible in sound as well as in playing method.

To answer my initial question, at the end of my research I conclude that microphones and loudspeakers hold a unique position in the realm of sound producers, a proposition that I have supported through developing four approaches towards them. It is especially the combination of their ability to function as physical sound producers (the tuning fork principle) and their ability to act as seemingly "transparent" sound transmitters (the tympanic principle) that makes them exceptional in the field of objects with which music can be made.

The future of microphones and loudspeakers: between air and electricity

The development of conventional musical instruments generally involves an intensive collaboration between musician and instrument maker. Microphones and loudspeakers are not expressly designed for the kind of application as in the musical works I described in the last two chapters, but principally for transmitting sound without becoming audible themselves. Thus, the search for the transparent microphone and loudspeaker continues. In microphone technology, for example, one might note the development of optic microphones, laser microphones and microphone array systems, using a large number of individual microphones for creating highly directional output. Although the microphone is already a highly sophisticated device, developments in the area of increased directionality as well as an increased use of digital signal processing might be expected (Rayburn 2011, 8).

Until recently, the Kellogs-Rice loudspeaker from 1924 (see chapter 2) has been the foundation for the majority of loudspeaker design techniques. However, several new technologies have been introduced in recent years, for example to develop loudspeakers which project their sound in a specific and focused direction, so that the person for whom the sound is intended can hear it and no one else is disturbed, or to develop ways of concealing the loudspeaker in a flat panel (Klaß 2009). These devices no longer incorporate a moving coil and stable magnet, but implement different technologies, for example that of using two attached membranes (Flat Flexible Loudspeaker, FFL (Klaß 2009)), the possibility of printing loudspeakers on paper with the use of flexo printing technology (Kolokathas 2012) or applying the thermoacoustic effect of carbon nanotube technology (Xiao et al. 2008, 4539). The result is that many of the techniques discussed in this and the previous chapter no longer apply to these new loudspeakers. For example, loudspeakers might utilise the thermoacoustic effect: if a temperature oscillation (a rapid change in the temperature of a particular material) is effected, a pressure wave will be excited as well (Xiao et al. 2008, 4542). This (air) pressure wave is perceived as sound to human beings as soon as the frequency lies within our hearing range. Another example might be loudspeakers constructed with carbon nanotube technology, which are flat, flexible and stretchable and can be tailored into many different shapes, or attached to all kinds of flexible materials, such as clothes or flags. Even if the thin film is partly broken, it still produces sound without distortion, which is impossible for the diaphragm of the conventional moving coil loudspeakers. The thin film of carbon nanotubes does not vibrate like a conventional loudspeaker diaphragm, so that attaching an object to it does not bring that object into vibration, the phenomenon used in the pieces by Tudor, Pook and Wassermann. Thirdly, the strong directional aspects of the FFL technology, no longer allow for an interaction between sound and space, as used by Nono. If these technologies for flat loudspeakers become established—and they probably will, since the transparent loudspeaker still forms an ideal for the sound reproduction industry—new opportunities for composing with microphones and loudspeakers will certainly come into existence as well.

Although the technology will change, the main characteristics of microphones and loudspeakers will most likely remain the same. The devices transduce sound waves into electricity (or perhaps another form of energy) and back, but are intended to remain "inaudible". As the examples above show, current developments are focused on making microphones and loudspeakers smaller and flatter. Composers and musicians will be dependent on what the sound reproduction industry develops in the future to facilitate transparent sound reproduction, a paradigm quite different from that applied in the development of objects to be used only as musical instruments. Whereas for these "real" musical instruments, the wishes of musicians and composers for the instrument as music *producer* are central, microphones and loudspeakers remain in what I called the second category of objects with which to make music (see chapter 2): devices which deal with sound but which are not intended to produce music in the same way as a conventional musical instrument. The new developments described above thus take place in the absence of any substantial influence by artists who use microphones and loudspeakers for developing musical performances. What artists might wish for is probably to realise further possibilities of interaction with microphones and loudspeakers through movement, material or space, the three categories I mentioned in chapter 4. For movement, it would be desirable to have microphones and loudspeakers which are very light, wireless and/or rotatable in all directions. Whereas these features are partially available in the current microphones and loudspeakers, improvements could certainly be made. Wireless loudspeakers are not yet very common, and the wireless microphone does not have a large movement radius due to the relatively large transmitters which it often requires. Regarding material, flexible microphones and loudspeakers which could be attached to all kinds of materials, such as clothes, and/or cut into all manner of forms, would certainly be desirable to many artists. For interacting with space, more control of the directionality of microphones and loudspeakers could be achieved, especially the latter, making it possible for example to focus the sound in a line through space, which would be interesting for both artistic and commercial applications. What all of these developments have in common is once more a different way of dealing with sound from that found in any acoustic musical instrument.

The technical construction of microphones and loudspeakers will certainly change in the near future. It might be that the moving-coil loudspeaker, as described in the Kellogs-Rice patent, will become obsolete. Many of the musical works I described in the last two chapters will then become subjects for historically-informed performance practice. However, the necessity of implementing some transformation between air pressure waves and electricity (or some other form of energy) remains. Although their main function will probably be to transmit sound without being "audible" themselves, and though they may become more and more "invisible", microphones and loudspeakers will retain their physical presence, and artists will find new ways to interact with new kinds of microphones and loudspeakers.