Between air and electricity : microphones and loudspeakers as musical instruments

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2 Four approaches towards microphones and loudspeakers: reproducing – supporting – generating – interacting

Four approaches towards microphones and loudspeakers

Given that microphones and loudspeakers became so omnipresent in music during the last century, it is no surprise that the question of whether they were instruments or mere reproduction devices would arise. In this chapter I discuss the relation between microphones and loudspeakers on one hand and musical instruments on the other. In the course of my research, I realised that the delineation of what we regard as a musical instrument is not at all as straightforward as it might seem, and that the possible relationships between microphones and loudspeakers in relation to musical instruments are much more complex than I had initially supposed. For this reason my subtitle *Microphones and Loudspeakers as Musical Instruments* became one of my principal questions: are microphones and loudspeakers musical instruments?

To address this question, I analysed the different relationships microphones and loudspeakers might have to musical instruments. Categorising the use of microphones and loudspeakers in musical practices in terms of different "approaches" by musicians and composers turned out to be very helpful. As a result of a thorough analysis of microphone and loudspeaker use in musical practice, I developed four approaches towards microphones and loudspeakers. The fourfold classification may sometimes seem rather artificial, since most microphone and loudspeaker use in musical practice cannot be assigned solely to one of these approaches, but will often also have some connection to one of the others. However, as I demonstrate in chapter 5, these approaches are helpful not only for analysing the different uses of microphones and loudspeakers, but also possibly as a point of departure for composing for these devices.

Music and musical instruments

Since I am undertaking research on microphones and loudspeakers as a composer, my first connection to these devices is through the practice of making music. One might observe that music, in general, seems to be made with the help of musical instruments. But what happens when microphones and loudspeakers are essential to the music-making process? Could these devices be considered musical instruments as well? In chapter 1, I clarified, in the context of my research, the function of microphones and loudspeakers: they are used for transformations

between air pressure waves and "something else". But what are musical instruments? Which objects should be considered musical instruments, and which should not?

The assumption that music is made with instruments seems to be so largely accepted that there is little doubt about the crucial relationship between music and instruments or ambiguity about what musical instruments might be at all.[13] As the philosopher Philip Alperson says, "the idea of the musical instrument seems central to our understanding of the musical art" (Alperson 2008, 37). However, defining what those objects called "musical instruments" actually are can prove problematic, as the article on the *Classification of Instruments* in The New Grove Dictionary of Music and Musicians puts into words: "'Musical instrument' is a self-explanatory term for an observer in his own society; it is less easy to apply on a worldwide scale because the notion of music itself in such a wide context escapes definition" (Wachsmann et al. 2013). Instruments are thus so closely connected to the performance of music that they seem to be inseparable from music itself. If an artist wants to make music, he or she will do this with the help of musical instruments.[14] The instrument seems to be not only a transportation vehicle for music but also a premise for its existence. The composer Atau Tanaka describes this relationship well: "If concert performance is the medium of communication then the instrument becomes the conduit between performer and listener. The listener's perception of the music is contingent on the instrument's efficiency at transmitting the performer's musical expression, and the performer's ability to channel his creativity through his instrument" (Tanaka 2000, 389).

[13] For an investigation of definitions of musical instruments, see the article *What is instrumentality in new digital musical devices? A contribution from cognitive linguistics and psychology* by Cance, Genevois and Dubois (2009). This article reveals that many definitions of musical instruments are tautologies: for example, "an object or device for producing musical sounds", quoting the *New Oxford American Dictionary* of 2007 (Cance, Genevois, and Dubois 2009, no page numbers), or seen as impossible: for example, as phrased by André Schaeffner, "Can we define the term musical instrument? It is impossible, as well as we cannot state any precise definition of music that would be valid in every situation, every period, and every use of this art." Quoted from *Origine des instruments de musique. Introduction ethnologique à l'histoire de la musique instrumentale* (Schaeffner 1968, 9) in (Cance, Genevois, and Dubois 2009, no page numbers).

[14] The human voice is often regarded as an exception among musical instruments, since it has not been purpose-built. In the twentieth century it became common though to refer to the the human voice as a musical instrument. It is, for example, the first instrument discussed in *Instrumentation in der Musik des 20. Jahrhunderts* (Gieseler, Lombardi, and Weyer 1985).

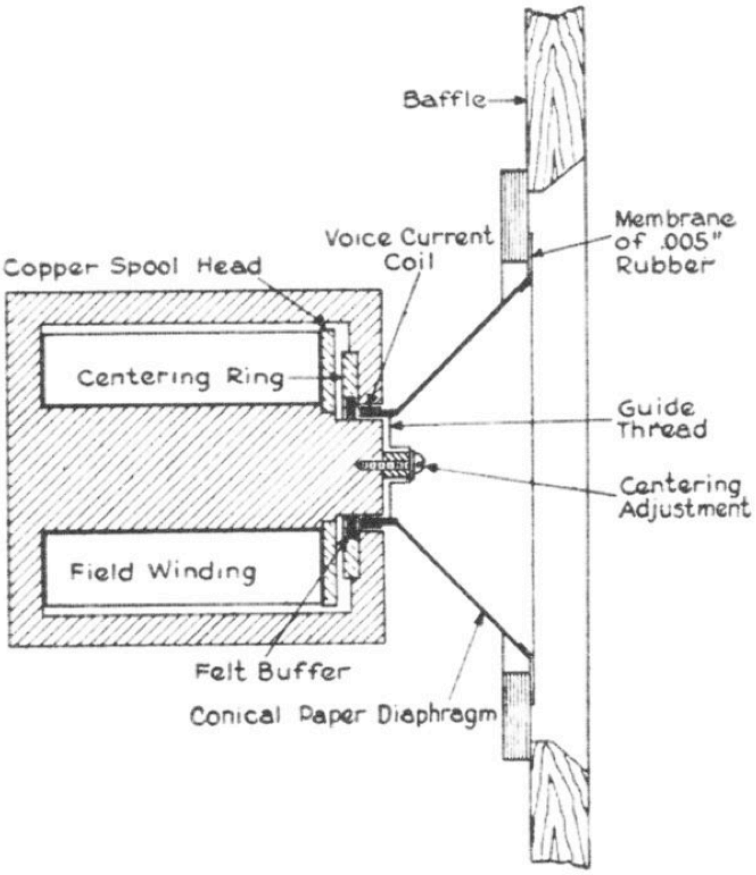
Musical instruments defined in the context of microphones and loudspeakers

The idea of what is considered to be a musical instrument is strongly defined by the society in which it emerges. Therefore, it makes the most sense to look at instruments and their relationship to microphones and loudspeakers within a pre-defined context. For this purpose I go back to the time of the invention of microphones and loudspeakers. As with most new technologies, there is no one particular date or invention that forms the starting point. Prior to the existence of microphones and loudspeakers, many of their applications had been to some extent already achieved, using horns for amplification (in fact focusing of soundwaves), for example. The entrance of microphones and loudspeakers into music-making practice should be seen as a continuous development taking place through the second half of the nineteenth century and the first quarter of the twentieth century, taking as a possible starting point the year 1857, in which the phonautograph was invented by Léon Scott*. This was one of the first devices developed for the purpose of recording sound waves. The loudspeaker construction described by Chester W. Rice and Edward W. Kellogg in 1925 in their famous article on loudspeakers (Rice and Kellogg 1925) is often seen as a significant stage in the aforementioned development, since this device produced, in combination with electric amplification, a level of sound quality high enough to initiate the mainstream application of microphones and loudspeakers in sound recording, sound reproduction, and sound amplification for radios, concert halls and, a few years later, cinemas.[15] It is between the years 1857 and 1925 that many prototypes of devices, such as the telephone, radio and phonograph, nowadays classified as "sound reproduction technology" devices, were invented.

To obtain an idea of what was regarded as a musical instrument during this timespan, I examine two concepts regarding the identity of a musical instrument which were in circulation around the beginning of the twentieth century. The first was formulated by music-ethnologists Erich Moritz von Hornbostel and Curt Sachs, who developed what became a famous classification system for instruments at the beginning of the twentieth century (Hornbostel and Sachs 1914), which is still appreciated by many contemporary musicologists.[16] As Hornbostel mentions in an article in 1933 on African sound instruments: "for purposes of research, everything with which sound can be produced intentionally must count as a musical instrument, and, for this reason, it is advisable to use the term 'sound-producing instruments'" (Hornbostel 1933, 129). This definition should be regarded as rather revolutionary in the context of its time, since it implies that everything "with which sound can be produced" can become a musical instrument. This broad definition of what a musical instrument might be should be seen in the context of Sachs

[15] Overviews of patents of sound reproduction technology can be found online: (Ehlert 2004) and (Ubu Web 2011).

[16] Margaret Kartomi gives a good overview of instrument classifications as well as outlining the influence of the Hornbostel and Sachs system on many classification systems (Kartomi 1990).



A scheme of a moving coil loudspeaker from the Rice and Kellogg article. When comparing this scheme with the loudspeaker scheme in appendix 2, it is striking how little has changed in the construction of moving coil loudspeakers nowadays.

and Hornbostel's ethnological approach. Whereas many earlier definitions had focused on typical Western European characteristics of music, they attempted to include all kinds of instruments without articulating aesthetic boundaries as defined by a specific expectation of what music is. Heinrich Christoph Koch's *Musikalisches Lexikon* of 1802, for example, claims that a musical instrument should produce tones, thus implicitly excluding noises. His remark that the ideal instrument should come as close as possible to the human voice underlines this idea (Koch 1802, 779–780). The second unconventional aspect of Hornbostel's definition is that he draws no predetermined line to distinguish sound from music. According to this idea of what an instrument is, any sound can be part of a musical performance, and no sound is *per se* unmusical. Here again, the ethnological approach, in this case applied to the investigation of African sound instruments, results in a much more open approach as to what an instrument—as well as music itself— might be.

Although this definition of a musical instrument is rather broad, Hornbostel underlines his conviction that the sound should be produced intentionally. The intention of producing sound

with these "sound-producing instruments" can be linked to the idea of the transportation of music, and here I refer back to Tanaka's statement (Tanaka 2000, 389). This idea of musical instruments as transportation vehicles for music can be found in radical form in the work of Hugo Riemann*, whose theorising on musical instruments forms my second example from this time period. Riemann considered the performance of musical works to be a mere transference of the musical proceedings from the fantasy of the composer into the head of the listener (Riemann 1916, 2). Musical instruments are, in this case, nothing more than devices through which music in a certain manifestation may be channelled. Regarded in this way, music's manifestation in sound is not necessarily its only form of existence: reading a musical score, for example, is regarded by many as a way to apprehend the musical performance notated there (Heilgendorff 2008, 117).[17]

If I consider Hornbostel's and Riemann's ideas concerning musical instruments and apply them to microphones and loudspeakers, I have no hesitation in calling these devices musical instruments. They are indeed producing sound, and this sound is produced intentionally (namely in order to play music). Furthermore, if musical instruments are nothing more than transportation vehicles for musical ideas, as Riemann suggests, then microphones and loudspeakers could even be regarded as ideal musical instruments in a certain sense—since they do not (theoretically!) add any sound of their own to the "music itself", they could be seen as an ideal vehicle, transporting the sound between the mind of the composer and the mind of the listener. In the first chapter I have already described some of these "immediate" transportations of music from composer to audience by means of loudspeakers.

As self-evident as the role of the instrument is in music, it also seems quite as self-evident in contemporary society that the loudspeakers in our living room are not musical instruments at all. When listening to one of Bach's *Six Suites for Unaccompanied Violoncello* through loudspeakers, most people would probably regard that what they are hearing as the music performed by a violoncello, and not by a piece of cardboard, moving forwards and backwards to produce sound waves.

Hornbostel and Riemann both developed their ideas on musical instruments in the era prior to the existence of microphones and loudspeakers. The invention of sound reproduction technology —of which microphones and loudspeakers were essential parts—calls into question those ideas about instruments which had been established by the end of the nineteenth century. In this, it is relevant to redefine what a musical instrument is in the context of my research on microphones

[17] I will not go into detail concerning questions such as what might be the musical work, the role of the score, or the performance of the score, since this would lead me too far away from my subject. Much has been written about this, for example in *Zu Einer Theorie Der Musikalischen Reproduktion: Aufzeichnungen, Ein Entwurf Und Zwei Schemata.* (Adorno 2005) and in *The Imaginary Museum of Musical Works: An Essay in the Philosophy of Music.* (Goehr 2007).

and loudspeakers. As I establish in the next paragraphs, many sound reproduction technologies used in music were indeed, at their time of invention, termed musical instruments. During the first thirty years of the twentieth century, however, a clear division between musical instruments and sound reproduction technology was established. At the end of the 1920s, sound reproduction technologies were able to become mainstream due to electric amplification. The last highly visible element of the technology which could be traced to a conventional instrument —the "horn" used for amplification—was removed from sound reproduction devices. Due to this development, most people nowadays would never call the act of playing a CD in their living room "performing music".

Three categories of objects with which music can be made

The sole function of musical instruments is often to produce music: pianos, guitars, violins and percussion instruments are designed solely for this purpose. Whereas the origin of all musical instruments must lie in material not specifically created for music making, such as bones, stones, reeds and sticks, they are all adapted in various ways in order to fulfil a musical function. The resulting object is meant to be used for making music, and nothing else. This might be one of the main reasons that the "musical instrument character" of all objects which otherwise perform functions other than that of making music, but which have been introduced into the creation of music, is often intensely discussed.[18] If music is dependent on musical instruments, and these instruments are the connection between composer, performer and listener[19], what happens when music is made with objects that were not created solely to make music? Are they still as good at transmitting the performer's musical expression, as Tanaka proposes? Is a mixing desk a musical instrument? And what about turntables, radios, laptops and sirens? Or spoons, bikes and wine glasses?[20] These objects sometimes form part of a musical performance, and sound is produced with them intentionally, so they fit into Hornbostel's definition. At the same time, none of these objects are officially termed "musical instrument". Whereas turntables and mixing desks

[18] A classical example is the question up for discussion: whether or not the laptop or computer is a musical instrument (Evens 2005, 130).

[19] I must underline that these three functions – composer, performer, and listener – can very well be incorporated in one person.

[20] All these objects have been part of several musical performances, and some of them, such as glasses and spoons, even have a tradition of being used in music for many centuries. Think, for example, of the mixing board-only performances by Marko Ciciliani, turntable artists like Christian Marclay, radio pieces like Joanna Bailie's *On and Off 2*, sirens in the compositions of Edgard Varèse, the virtuoso spoon performances by Tran Quang Hai, the singing bicycles used by Godfried Willem Raes in his second symphony, and the use of wine glasses in compositions by George Crumb.

are at least closely related to sound and music, the usual functions of spoons and bikes are not related to music at all.

To approach the use of different kinds of objects in music, I define three categories of objects used as musical instruments. The first category consists of objects that are developed for the sole purpose of making music. Even if they could have another function, for example as decoration in a living room (think of grand pianos), their main intended function is, without doubt, to make music. The second category consists of all devices whose main function is to deal with sound. In contrast to the first category, they are, in general, not identified as musical instruments, since their main function is not to make music, although they are often used to work with sound in several ways. All devices such as radios, CD players, mixing desks and also microphones and loudspeakers belong to this category. The third category includes all other objects used in music that are not associated with sound at all in their main function. Spoons, glasses and bikes are examples in this category.

The principal function of the latter two categories of objects is something other than making music. This does not mean, though, that these objects were not used in musical performances. To compose music for these objects often implies that the artist brings them within the realm of musical instruments. The unexpected use of the object as a musical instrument is seen as an important aspect of the performance. This is also the case for composers and performers working with microphones and loudspeakers. These artists approach such devices *as if* they are musical instruments, frequently even mentioning this explicitly in their scores or writings (see multiple examples in chapter 4).

I started this chapter with the question of whether microphones and loudspeakers are musical instruments. My conclusion until now—that microphones and loudspeakers belong to the second category of objects with which music can be made—brings me to several sub-questions of this principal question which I examine during the remainder of this chapter: why are microphones and loudspeakers generally *not* considered musical instruments? What are the principal functions of microphones and loudspeakers? What would be the "necessary treatment" required for them to be considered as musical instruments?

Acts of sound creation as opposed to the referential character of sound waves

Evidently, at the time when the devices now collectively referred to as sound reproducing technology were introduced, a division between these devices and musical instruments did not yet exist as such. As pronounced in Hornbostel's definition, everything utilised for the intentional production of sound should be considered a musical instrument. At that time, music

could not in fact be made by anything else, and the whole notion that devices other than musical instruments could produce music or, more correctly, *reproduce* music, grew alongside the technology which made such reproduction possible. The first questions to answer concern the difference between sound reproduction technology and musical instruments, and why microphones and loudspeakers are not in the first place considered to be musical instruments.

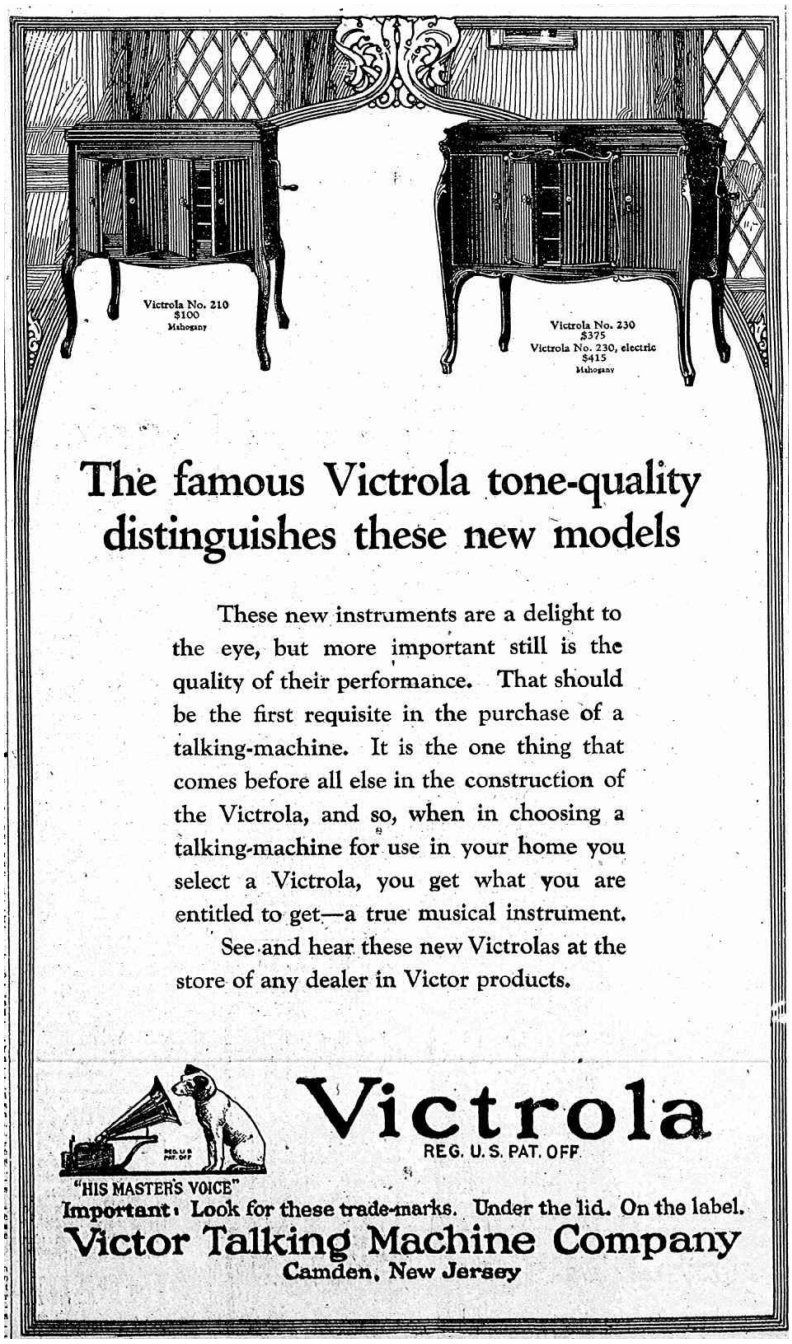
One similarity between sound reproduction devices and musical instruments is that both are used to produce sound and with the intention to produce music (both categories thus fitting into the Hornbostel definition). Musical instruments are specialised, however, in producing certain sounds much better than others, and most sounds (of the almost infinite spectrum of all possible sounds) are unplayable on a specific instrument. Sound reproduction technology was developed not for producing sounds, but for *reproducing sound waves*. This is the essential difference, from a technical point of view, between a musical instrument and a sound reproduction device. A good example is the comparison between a piece of music sounding from a player piano and the same piece being reproduced with a phonograph. The player piano is not reproducing sound waves, but reproduces the acts of sound creation according to how they occur in a piano performance. Several parts of the player piano move in specific ways, the end result of which is a particular sound. These acts of sound creation, as I will call them, are inherent to the characteristics of a musical instrument. This is the reason that I regard a player piano as a musical instrument rather than as a sound reproduction device. Every act of sound creation results in the production of sound waves, so every sound can—in theory—be reproduced by sound reproduction technology through the act of reproducing these sound waves. This universal approach of sound wave reproduction distinguishes sound reproduction technology clearly from musical instruments, including musical automata, which in my opinion also belong to the realm of musical instruments as they can only produce a limited range of sound creation acts. Sound reproduction devices are designed to reproduce sound waves and not to produce a specific sound, a task that is performed by musical instruments (see (Pierce 2001, 285) and (Sterne 2003, 71)).

Representing sound reproduction technology as musical instruments or musicians in advertisements

At the time of the invention of sound reproduction technology, this difference in technological focus of musical instruments and sound reproduction devices did not result in a clear division between the categories. On the contrary, producers of early sound reproduction technologies tried to convince their audiences that their new devices, developed during the end of the nineteenth century, were nothing other than musical instruments. Thomas Edison* himself thought the phonograph would become the greatest musical instrument in the world (Thompson 1995, 142). Many advertisements for phonographs and gramophones promised the consumer that they would be acquiring real musical instruments. A good example of this is the marketing strategy of the Victor Talking Machine Company (see picture (Anonymous 1922, 9)), "during the period from 1906 to 1921 [...] probably the most consistent user of advertising space in the entire United States" (Maraniss 1937, 9). Their gramophone even received a prize for musical instruments at the St. Louis Exposition of 1904 (Siefert 1995, 440). The reason, at the time, for emphasising that these devices were musical instruments was that musical instruments had always been necessary for the production of music. Thus, using that description in the publicity material of new devices, such as a gramophone, gave the impression that real music was produced by it (Siefert 1995, 432–433). Sound reproduction technologies were supposed to replace the role of the piano in the living room. Instead of young women (most of the time one of the daughters) who performed music on the piano, as was common in the nineteenth century (Blanning 2008, 183), at the end of the nineteenth century, a phonograph could be installed in the living room and perform (!) the same role. It may therefore come as no surprise that in some advertisements, the gramophone became the musician itself, as in this advertisement from the 1890s: "The Berliner Gram-o-phone talks distinctly, sings every song with expression, plays the piano, cornet, banjo, and in fact every musical instrument with precision and pleasing effect" (Sterne 2003, 164). These new devices were all-round performers of music and able to become any musical instrument.

From the phonograph as a musical instrument to the radio as a sound reproduction device

Two developments resulted in a shift in the perception of new devices, such as phonographs and gramophones, from musical instruments towards sound reproduction devices. First of all, their sound quality was improved enormously by the use of electric amplification. Electric amplification became mainstream in the 1920s and 1930s and made sound films possible, since loudspeakers had become loud enough to radiate sound into a small hall, such as a cinema. Also,



An advertisement of the Victor Talking Machine Company, calling a sound reproduction technology "a true musical instrument" of 1922.

radio used electric amplification instead of the traditional horn, as used by phonographs, to project sound. Owing to the introduction of the radio, the phonograph industry lost much of its popularity. A solution was found in using the same amplifying system for phonographs as for radio: since "the perfection of electrical sound reproduction has produced an instrument whose striking realism has given new life to that industry" (Harbord 1929, 63).

Before electric amplification, the phonograph horn was used for mechanical amplification (the horn is in fact focusing sound waves, not amplifying). Since recordings, according to the advertisements, had been already "high fidelity" from the beginning of sound reproduction,[21] even when using the horn, the company RCA Victor[22] decided to call electric amplification the "higher fidelity" system. With the introduction of electric amplification, the emphasis was no longer on the "musical instrument" (as the Victor Talking Machine Company promoted their phonograph) or on the machine as "musician" (as Berliner had advertised). The performance was not taking place in the same room anymore as the audience: "The evidence is in what you hear—a new and stunning kind of musical brilliance that almost makes you believe the performer himself is in the room" (Maraniss 1937, 10). The device itself was no longer the performer or a musical instrument itself, as was claimed in earlier years, but transmitted the performance into one's living room: the performance is happening somewhere else, and the machine reproduces a copy of this performance. Concerts of recorded music were performed in people's living rooms, often even including the same habits as during live concerts, including the distribution of programs and silence during the music (Katz 2004, 57). Due to the emphasis on the technology's ability to "copy" the reality of a musical performance perfectly, sound reproduction technology was eventually no longer perceived as a musical instrument, but as a neutral transmitter of the sound of musical instruments (Grossmann 2010, 185–192). Thus, the earlier representation of phonographs as delivering a "live" performance, just like an instrument or a performer, ultimately led to a division between sound reproducing machines and musical instruments.

Aside from the better sound quality, probably an even more important reason that sound reproduction technology came to be regarded as belonging to a category of its own was the increasing popularity of radio during the 1920s. Whereas the first transmission of regularly scheduled programs intended for reception by the general public occurred at the beginning of 1921 in the United States (Whittemore 1929, 6), by the mid-1920s more than 1000 radio stations had already been licensed (Harbord 1929, 61). The radio had a totally different

[21] For an account of the history of the idea of high fidelity see chapter 5 'The Social Genesis of Sound Fidelity' in (Sterne 2003, 215–286).

[22] This became the new name for the Victor Talking Machine Company after they were bought by RCA (Radio Corporation of America).

relationship to live performances in comparison with the gramophone. Whereas the same record could be played again and again in the intimacy of the living room, and the listener was, to a certain extent, still managing the performance by choosing starting and stopping times, the radio connected the listener to a musical performance happening somewhere else. The music heard on radio was often performed live in a studio. Even when records were played during a radio show, this was often done with a certain atmosphere of live music, such as through announcing the recording. Radio had a continuous timeline, and if you disconnected and reconnected later, you had missed part of the show. Listening to the phonograph resulted in a performance happening in your living room, but listening to the radio connected you to a performance happening somewhere else. It is probably this difference that caused the radio to become thought of as a reproduction device instead of as a musical instrument: "The aim of broadcasting is obviously truth—the life-like reproduction of the original performance" (Fitchew 1935, 889). The sound produced by the radio was not connected to the device anymore but to the location where the performance was taking place. The radio was conceptualised as connecting the listener with the performance "as an ideal of instantaneous transmission and reception, a communication without meditation" (Kahn 1994, 20).

One proof that the radio was not seen as a musical instrument may be found in several court judgements (Anonymous 1931, 1045 and Anonymous 1930, 343). In both cases, the court argues that the radio is not making any sound of its own: "a fundamental idea is contained within the definition of a musical instrument. This is the capacity of the instrument in and of itself when properly operated to produce the musical sound. A radio cannot do this. The musical instruments in the distant station, not the radio, produce and initiate the music within the definition before mentioned" (Anonymous 1930, 343).[23] Technically speaking, this is absolutely incorrect, since nothing else is making sound than the radio's loudspeaker(s). Whatever the radio is playing, the loudspeaker is the only sounding object. The seminal source of the sound, though, is, as the court states, the musical instrument in the distant station. Radio is thus most likely the invention for which, and as a result of which, the distinction between sound reproduction technology and musical instruments was instigated and established.

[23] This article also mentions that a minority does consider the radio to be a musical instrument. The article is concluded with the remark that "the radio may rise to the dignity accorded the saxophone and the jew's-harp" (Anonymous 1930, 344). The author of this article still has hope that one day the radio will develop into a musical instrument.

Musical instruments and sound reproduction technology

With the invention of sound reproduction technology, instruments were no longer alone in making "musical sound", or as Hornbostel calls it, making sound with intention. For the first time, when listening to music, one had to ask oneself whether this music was produced by a musical instrument or whether sound waves similar to the sound waves produced by a musical instrument were being reproduced by a sound reproducing device. A major change in musical performances was the disappearance of the need to have musicians performing on musical instruments in order to hear any music. New inventions, such as telephones, phonographs and radios, made it possible to listen to music everywhere, no longer demanding from the audience that they share time and place with musicians and their instruments.

As many authors agree, these new devices did change our relation to sound extensively, due to their ability to "reproduce" sound.[24] I will not give a survey of the differences in views as to what kind of changes occurred and how these were related to technology.[25] Instead, I focus here only on the alterations in musical performance and especially in our relation to musical instruments, since the introduction of microphones and loudspeakers. As I argued in chapter 1, the changes in music perception cannot be attributed only to the use of sound reproduction technology, but should be related also to changes in musical performance practice such as the *Konzertreform*. I have already discussed the difference between musical instruments and sound reproduction devices from a technical point of view: sound reproduction devices do not focus on sound creation but on reproducing sound waves. I also analysed audiences' perceptions of these new devices: they were identified as musical instruments when they were introduced, but soon developed into a new category, which we call today sound reproduction technology. In the following paragraphs I examine the difference between playing musical instruments and operating sound reproduction devices.

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[24] Some books, which cover this subject are: *Noise: The Political Economy of Music* (Attali 1985), *Repeated Takes: A Short History of Recording and Its Effects on Music* (Chanan 1995), *Klang (ohne) Körper: Spuren und Potenziale des Körpers in der Elektronischen Musik* (Harenberg and Weissberg 2010b), *Capturing Sound: How Technology Has Changed Music* (Katz 2004) and *The Audible Past: Cultural Origins of Sound Reproduction* (Sterne 2003).

[25] A short overview of different viewpoints can be found in *The Audible Past: Cultural Origins of Sound Reproduction* (Sterne 2003, 19–20).

Semantic acts of sound creation

Agreement as to what a musical instrument is, and which devices belong to the category of sound reproduction technology, is much less ambiguous today than in the early twentieth century. To explore the differences between these categories, I take a closer look at the way musical instruments and sound reproduction technology (re)produce sound. What are the characteristic acts of sound creation accomplished by musical instruments, and are these acts absent in the application of sound reproduction technology? To answer this question, I compare the playing of two kinds of musical instruments, namely clarinet and organ, and correlate these to the operating of a CD player. I look at the means of sound creation: what types of action are needed to play the instrument and what types of sound creation acts the listener perceives.

Playing the clarinet, for example, involves adding breath to create energy for air pressure waves and moving fingers to shorten or lengthen the pipe, with the help of keys that facilitate the closing and opening of holes in it. Whereas a clarinet player still has direct contact with the sound production, since it is his or her breath causing the sound, an organ player is already further removed from the act of sound creation. The "breath" for the organ is supplied by an extra mechanism (today often controlled by electric motors; in earlier days, human-powered). By pressing just one key on the keyboard, several pipes may be simultaneously activated, the equivalent of being able to play several clarinets simultaneously with the use of just one finger. From this point of view, the physical movements of an organ player can be interpreted as more detached from the sounding result than the movements of the body of a clarinet player. Pushing the play button on a CD player, however—an action not unlike pressing a key on the organ or clarinet—generates an entire piece of music. The "breath" is supplied by electricity. Whereas the difference between playing a clarinet, an organ and a CD player, in the analysis above, seems to be nothing more than a slight modification within the same category of performance, the clarinet and organ are generally considered to be musical instruments whereas the CD player is normally seen as a machine.

The reason clarinets and organs are classified as musical instruments and CD players as machines may be the following: during the playing of a clarinet or an organ, no other acts of sound creation are perceptible than the ones caused by the movements of the performer, whereas listening to a CD will result in the perception of manifold acts of sound creation. In the case of the CD player, the intention of sound production, as Hornbostel would call it, is more clearly linked to the referential character of the sound waves themselves (that is, to the recorded musical instruments) than to the sound creation itself (which consists of the mere act of pushing the play button). I term this referential character of sound waves the "semantic" act of sound creation. When playing a CD, the musical expression which is transmitted—a defining function of musical instruments according to Tanaka—arises not from the act of pushing the play button of

the CD player but from the acts of sound creation audible in the sound waves themselves. Thus several acts of sound creation are at work. The act of pushing the play button is so weakly linked to the resulting sound, as compared to all the acts of sound creation perceptible in the audible music, that often neither the CD player nor the amplifier nor the loudspeakers will be regarded as (part of) the musical instrument.

Recognising the music through the noise

When listening to a CD player, or any other sound reproduction technology, the semantic acts of sound creation are different than the acts of sound creation (pushing the play button). To recognise the semantic acts of sound creation—which instrument is playing on the recording—sound reproduction technology itself should be "silent". If one listens to wax cylinder recordings from the end of the nineteenth century, it is almost incredible that through all the loud noise, one is able to recognise any music at all. How is it possible to distinguish between recorded sound (the semantic acts of sound creation) and the noise of the sound reproduction device itself?

What follows may seem contradictory to my previous discussion of the phonograph being regarded as a musical instrument. At the beginning of the twentieth century the phonograph was seen as being able to reproduce all musical instruments. However, by this I do not mean to suggest that those listening to a phonograph performance did not recognise that the instrument "played by the phonograph" was a violin. The identification and differentiation of which sound on the recording belongs to which musical instrument (the referential potential of the sound waves) and which sounds are added by a sound reproducing device (all the humming and noise on the recording) was already practiced very early, when sound reproduction quality was still very low. The capability of human beings to focus on the music in these recordings and to minimalise the perception of noise is a result of what is called Gestalt laws of grouping. During listening, common fate is one of the dominant grouping principles, and we therefore hear partials which frequencies move in parallel, as belonging to the same sound "cause". The cause is the vibrating object producing sound waves, such as a violin. We also tend to give these groups of partials more attention than random sound in which the frequency and amplitude of the partials do not relate to each other. As the cognitive scientist Roger Shepard mentions, these grouping laws are "'wired into' our perceptual machinery. They do not have to be learned by trial and possibly fatal error, because they generally hold in the real world" (Shepard 2001, 34). Our brain easily distinguishes between noise produced by the sound reproduction devices themselves and music created by musical instruments. With the Gestalt laws of grouping in mind, it is obvious why this happens: the music on these early recordings is melodic and rhythmic. The partials of the music are easy to distinguish from the noise on these recordings, since all these partials change together in pitch and rhythm, as opposed to the noise of the sound reproduction device.

The partials of noise do not have a particular relationship to one another, and almost no collective changes in pitch or rhythm take place. When listening to old wax cylinder recordings which have an extremely high amount of noise, it even proves difficult to try to ignore the music that is played and focus solely on the noise. To be as recognisable as possible, the music documented on these early recordings focussed not only on melody and rhythm, but also on qualities differentiating the sound produced as much as possible from the noise of the machine. Singing was especially suitable for recordings, particularly by opera singers with trained voices. Caruso's voice, for example, was regarded as very suitable for recording, remaining clearly recognisable against the noise of the needle on the surface of the record. As early as in 1902, his recordings were already considered to be "completely satisfactory", probably because "Caruso's strong tenor voice (with its baritone quality) helped to drown out the surface noise, so that even on the inadequate apparatus of the time, his records sounded rich and vibrant" (Chanan 1995, 30). The fact that already at a very early stage the phonograph was able to give the impression of a recording of a specific instrument underlines that aesthetically acceptable sound reproduction was already possible.

Electricity decouples movement and sound

For the purposes of my research I defined microphones and loudspeakers as devices used for the transformation of air pressure waves into "something else" and back. I also mentioned the importance of the introduction of electricity in sound reproduction technology, and I outline below why this transformation of sound into electricity is such an important development for the use of microphones and loudspeakers in making music. Whereas a phonograph functioned entirely without it, electricity was essential for telephones to be able to transport sound waves from one place to another. The significant difference between mechanical and electric sound reproduction technologies is this transduction into electricity, since it creates the possibility of eliciting changes in these waves between the input (the microphone) and the output (the loudspeaker). As soon as it has been converted to electricity, a recorded sound can be processed in numerous ways. Any sound characteristic can be changed in between microphone input and loudspeaker output. All mechanical sound reproduction technologies are connected to the material which stores or transports them: there is no possibility of changing the relationship between what was recorded and what is reproduced, since both sides of the process are connected to the same material.[26] This is best demonstrated by early sound reproduction technologies, such as the phonograph: the same wax roll is used for recording the sound as for reproducing it. As long as the subject of research is sound reproduction, this distinction is not

[26] Turntable techniques are related to acoustic laws: for example the so-called scratching that is achieved by moving the record back and forth. The faster the record is played, the higher and shorter this sound is.

important, because there should be as little alteration possible between the sound that comes into the microphone and the sound produced by the loudspeaker. Jonathan Sterne, for example, sees all sound reproduction technologies united in the use of transducers from sound into something else and then back to sound, whether using electricity or any other medium, such as tinfoil or wax (Sterne 2003, 22). His research focuses, however, on telephony, radio and recordings, all of which have as aim to create the least possible alteration, or at least the impression of no alteration, between the sound at the input of the sound reproduction technology and the sound at the output of that technology. My view on this topic is from the perspective of a composer, and as such, I often regard changes between input and output sound as one of the principal goals. The physical grooves of a record cannot be modified, and indeed scratching in turntablism is a technique typical for a non-electrical instrument: the sound waves are just reproduced a little bit faster, resulting in higher frequencies. But an electric current is easily modified according to other principles than mechanical laws, and musicians and composers gratefully started to use this feature.

The introduction of electricity as a sound source has been commented upon by many as one of the most influential changes in music-making which took place in the last centuries. Konrad Boehmer* goes as far as to call this the *terza prattica* (Boehmer 2004, 159), giving the introduction of what he calls "an authentic electric music"[27] the same weight as the paradigm shift from *prima prattica* to *seconda prattica* in the seventeenth century.[28] "What was previously characteristic of the breakthroughs of the *prima prattica* and the *seconda prattica* is no less valid for the historical perspectives of a *terza prattica*: there can be no new art forms without a new understanding of the world, without an understanding of a new world" (Boehmer 2004, 168). Boehmer finds the development of "an authentic electric music" as important as the introduction, more than a thousand years ago, of the notation system for music. Clearly, according to Boehmer, this new practice of electric music has not yet been fully developed.

The philosopher Peter Szendy observes that the use of electricity in music generates a totally new relationship between the music making "bodies" (seeing not only the musician him- or herself as a body, but the musical instrument as well), resulting in a totally different coupling of these bodies from what had been possible without electricity (Szendy 2002, 133). Whereas, with a mechanical musical instrument, the player needed to be within a certain proximity to the

[27] It should be mentioned here explicitly that Boehmer postulates the terza prattica as playing a completely new aesthetic and social role. Use of electricity is thus not the only criteria resulting in a piece of music being part of the terza prattica (Boehmer 2004, 165).

[28] The prima prattica, also called stile antico, is a musical practice centering around vocal polyphony with strict counterpoint. The more monodic style, using more regular rhythms as well as more (so-called) vertical harmonies is seconda prattica, also called stile moderno. The change from prima to seconda prattica during the seventeenth century has been seen as a very important shift of paradigms in music.

instrument, with electricity the instrument can be played at a distance without having to take any laws of classical mechanics into account. An organist, for example, can control organ pipes at enormous distances with the help of electricity. Various authors take the elimination of the relationship—unavoidable in earlier times—between the musician's movements and the quality of the resulting sound, due to the use of electric sound production, as a starting point for intensive research on this topic in the book *Klang (ohne) Körper* (Harenberg and Weissberg 2010a, 7). All the authors mentioned above confirm that the introduction of electricity not only changed the relationship between the musician and his or her instrument, but that the whole praxis of music became thereby something completely new.

Microphones and loudspeakers are of course important agents in all these new possibilities for music, situated as they are between the material world of air pressure waves and the virtual world of electricity. It has become increasingly rare for a piece of music not to confront the listener with microphones and loudspeakers. Most music heard these days, whether from a CD played at home, amplified instruments during a concert, or an MP3-player with earphones on the go, comes to the listener in the form of sound waves produced by one or more loudspeakers. In fact, all of the different acts of sound creation existing in music made by musical instruments are diminished to just one general action, namely the vibration of a very thin loudspeaker diaphragm. Whereas this sound production method is the same for nearly all music (excepting unamplified live music performances), the perceived acts of sound creation are rarely attributed to these thin diaphragms, but rather to the recorded or amplified instruments.

Approach 1: reproducing

Now that I have argued that a majority of music nowadays has some dependency on microphones and loudspeakers, I take a closer look at various approaches, examining the use of microphones and loudspeakers in relation to musical instruments. The first is that of reproducing music performances with the help of sound reproduction technology. I discussed most of the characteristics of this approach in chapter 1, in my analysis of the reproduction of music using microphones and loudspeakers. What is most remarkable about this approach is the premise that one general sound system, such as the common stereo loudspeaker system in a living room, is able to reproduce all music. Most importantly, in this scenario microphones and loudspeakers should act like transparent devices, adding no sound of their own, thus reproducing a musical performance with "high fidelity", as I outlined above in the discussion of the advertisements by the Victor Talking Company. Obviously this quest for high fidelity is endless, since every new invention in the realm of microphones, loudspeakers or any other aspect of sound reproduction technology has as its goal reproducing the music performance with ever higher fidelity. A performance heard through loudspeakers should not be thought of as

being produced by loudspeakers: the impression of a concert happening behind curtains is the main aim of a good recording. Especially in the case of the classical music recording industry, many recordings profess to reproduce the concert experience in the living room. There should be no significant difference in the experience of listening to a symphony by Beethoven at home through a hifi-system to that of listening to the same symphony in a concert hall performed by an orchestra. This *reproducing* approach is very common, given that a recording might be called the "normal" way to be confronted with music nowadays, replacing the live performance, as practiced before the introduction of sound reproduction technology (Gracyk 1997, 139).

Approach 2: supporting

Apart from *reproducing* already existing music performances, microphones and loudspeakers are also used in another constitutive approach: they are involved in what I term *supporting* the sound of musical instruments. Whereas sound reproduction brings music into people's living rooms, the *supporting* of musical instruments by microphones and loudspeakers happens mainly on the concert stage. The role of these devices when supporting a musical instrument might be compared to the soundboard of a piano or the corpus of a violin. The soundboard or corpus are an essential component of the instrument, and are also at the same time reliant on other parts of these instruments. The main function of the soundboard of a piano is to transmit vibrations produced by strings that have been hit by a hammer. Soundboards are not amplifying the sound, since amplification is only possible when adding energy to the vibrations. But due to the greater surface of the soundboard in comparance with strings, the vibrations will be easier transformed to air pressure waves, and thus sound. For this reason, the resulting sound will be much louder. In electric amplification not a soundboard is used, but a loudspeaker diaphragm. Since this loudspeaker is controlled by an alternating electric current, the vibrations of the diaphragm can be enlarged and real amplification of the signal is thus possible. The instrument would clearly be incomplete without the soundboard, but something would still be sounding (albeit much softer and shorter than the customary piano sound). Conversely, the soundboard alone cannot function independently; it is supporting the instrument, in this case, the piano. Based on this understanding, I define the *supporting* approach for microphones and loudspeakers as manifested, for example, in electric guitar or voice amplification: they can be considered as a supporting component of an instrument, whose core acts of sound creation are the guitar strings or vocal chords.

At the beginning of the twentieth century, when electric amplification was introduced to support musical instruments, microphones and loudspeakers were not yet seen as adding any sonic characteristics to the instruments they were amplifying. The main aim for using microphones and loudspeakers on stage seems to have been the creation of musical instruments able to

produce sound at higher volumes. This was needed since audiences had grown larger, and thus became more noisy, and performances took place in larger halls (McSwain 2002, 189). This was part of a development already going on since the beginning of the nineteenth century. Many new inventions in acoustic instrument design were introduced during that period in order to make instruments louder. A good example is the metal frame of a grand piano, making it possible to greatly increase string tension and, therefore, to produce more volume. In this quest for louder musical instruments, amplification of sound with the help of electricity was introduced at the beginning of the twentieth century. As John J. Comer* states in his patent of 1910, his invention is designed as "the receiver of an instrument for reproducing or transmitting musical vibrations" (Comer 1910, 1). What Comer calls a receiver is nothing other than an early loudspeaker. The name "receiver" is derived from the receiver of a telephone, the part through which one hears the voice of the other person. Comer further argues that this receiver "has for its object to produce sounds of greater volume and of purer and truer tone than heretofore" (Comer 1910, 2). Comer mentions that the sound of the instrument changes to what he calls "a purer and truer tone"). Instead of regarding this as an alienation of the main instrument, Comer regarded the amplified guitar as even closer to the "true" instrument than the unamplified version. As was described in many patents as late as the 1930s, the sound of the amplified instrument would be the same as the sound of the unamplified instrument. The only difference would be a louder volume (McSwain 2002, 193). This technological addition did not have as its aim that of changing the character of the original instrument. The developments in music, such as, for example, the highly modified construction of an electric guitar as compared to an acoustic guitar, or the different singing techniques developed as a result of voice amplification, clearly reveal that this technology had much more impact than solely that of increasing the volume of already existing musical instruments.

Transparent technology

The idea of only changing the volume of the instruments by amplification, without changing anything else (for example the tone colour of the instrument or the spatialisation of the sound), can be seen as corresponding to the idea of the reproduction of a concert in the living room, since here, again, the microphone, amplifier, and loudspeaker should be transparent and remain "inaudible". Exemplifying this, in audio-engineering circles a perfect amplifier—that is one that distorts the electrical signal not at all—is commonly called "a straight wire with gain".

When I speak about transparent and inaudible microphones and loudspeakers in the reproducing and supporting approach, I must underline that I am not referring to technical possibilities, but about how the technology is perceived or even the cultural consensus of how it should be perceived (which means, in this case, that the technology should not be perceived at

all). The music should sound as if produced by a human body interacting with a musical instrument, not with technology. Already this distinction between technology and musical instrument reveals the complication of this division, because is not every musical instrument a technological construction itself? Innovations in musical instrument design are often contemporaneous with technological developments occurring in fields not related to musical practice at all. The knowledge contributing to the development of valves for trumpets and horns, as well as gear, cranks and levers for timpani was transferred from technologies unconnected to music (Bowles 1999, no page numbers). A piano is built through the application of an enormous amount of technology and "is a machine. That may not be the first word that comes to mind to define the instrument, but is perhaps the most inclusive […]. A machine accomplishes work, that is, it applies energy to some end. The piano's energy produces musical sound vibrations" (Good 2001, 2).

The idea of an "inaudible" technology is older, however, than sound reproduction technology. The technology of an instrument, such as the operation of the valves, keys and pedals, should also be inaudible. The movements of the keys and pedals of, for example, a grand piano should as a rule not be heard during a conventional piano performance. The same can be said about the supporting role of microphones and loudspeakers: hearing a singer amplified through microphones, amplifier and loudspeaker rarely results in the audience perceiving a musical instrument consisting of singer, microphone, amplifier and loudspeaker. The main perception will remain that of somebody singing, whatever other technology is added to the voice. Of course the sound produced here is a result of the incorporation of all elements involved: the voice of the singer, the microphone, the amplifier, the loudspeaker and even the performance space. The sound produced is affected by a combination of all of these elements, but the semantic acts of sound creation are associated with only the singer.

New technology but conventional musical instruments

In both approaches, the concept of *reproducing* and *supporting* what a musical instrument does or its role in creating music, does not change as a result of the introduction of microphones and loudspeakers. These devices function simply as a new addition to an existing musical instrument. The additions might be seen as modifications of the instrument, just as the change from wooden frame to metal frame in grand pianos also changed the instrument's volume and timbre, however, the instrument remained a piano.

Within the concept of the *supporting* approach, I include those loudspeakers used in instruments invented during the 1920s (such as the theremin, trautonium and ondes Martenot), although they are a special case. These new instruments all use electricity to produce sound. The use of

loudspeakers was essential, since only thus could the sounds become audible. Unlike voice or guitar amplification, the loudspeakers are an indispensable part of the musical instrument itself. Instruments like the theremin were the first ones which needed a loudspeaker in order to be able to produce sound at all. In the realm of sound production, these instruments were important inventions, making audible sound entirely with electronics. Sometimes the design of the loudspeakers used, for example the three loudspeakers of the ondes Martenot, reveals that the loudspeaker was seen as the sound producer for these instruments and not as a neutral transducer from electrical signal to air pressure waves. Of the three loudspeakers of the ondes Martenot, one is prepared with a metal plate (called *métalique),* a second with sympathetic strings (*palme*), and the main loudspeaker contains some metal springs usable for reverb (*résonance*) besides a plain loudspeaker (*principal*) (Cramer 2008, 142). These objects resonate due to the air pressure waves produced by the loudspeaker diaphragm and, so doing, create additional sounds. The ondes Martenot loudspeakers are remarkable for their individual design. Another remarkable invention in this realm is the Leslie tone cabinet, using rotating loudspeakers and designed for emitting the sound generated with a Hammond organ (Limina 2002, 15–17).

The aim of the inventors of these new instruments using new technology was to prove that their inventions were equal to conventional musical instruments. The idea of what an instrument is did not change at all as a result of these new inventions; quite the contrary. A good example is the introduction of the theremin. To prove that the theremin is efficient in transmitting the performer's musical expression—coming back once more to Tanaka's definition (Tanaka 2000, 389)—just as the violin or violoncello are, pieces written for those older instruments have been played on the theremin. A talented violin player, Clara Rockmore, met Lev Termen, the inventor of the instrument, in the 1930s, and learned to play the theremin, performing well-known pieces, by Tchaikovsky and Saint-Saëns, originally composed for violin or violoncello (Cramer 2008, 134–135). With these compositions an immediate comparison could be made by the audience, since they already knew this standard classical music repertoire. An account of the first concert of a chamber orchestra of theremins at the Carnegie Hall in 1932 mentions the performance of popular pieces like *Aase's Death* (1875) by Edvard Grieg and the prelude of Richard Wagner's *Lohengrin* (1850). This was seen (or better said heard) as a proof that a performer could still perform the well-known music repertoire in the same expressive way on the new instrument. This "foreshadows a new era in which electrical musical instruments will take their place beside such time honoured instruments as the violin and the piano" (Anonymous 1932, no page numbers). The theremin was presented as an instrument that was as "musical" as all other existing instruments. Although "the audience was keenly interested in the new timbres and acoustical effects obtained" by these new instruments (Anonymous 1932, no page numbers), they did only hear music that was more than 50 years old.

The three different loudspeakers of the ondes Martenot: the *palme* is placed upon the *principal/ résonance*., the *métalique* is at the right.

Nonetheless some advantages compared to conventional musical instruments were remarked as well. By comparing the quality of loudspeakers as sound producers with conventional instruments, it was mentioned, for example, that "the surface of sound-emission from the speaking-cabinet and therefore its carrying power is more circumscribed than that of the Pipe Organ; but there is compensation in the fact that these speaking-cabinets[29] may be placed in the building where you will and as many as you will" (Galpin 1937, 81). The possibilities of the multiplication of sound sources as well as the loss of the constraint that sound is bound to the place where it is shaped were explored in-depth by composers and musicians in the second half of the twentieth century, as I will deal with in chapter four.

[29] The term "speaking-cabinet" as well as "sound-cabinet" is used by Galpin in this article as a synonym for "loud-speaker".

Reproducing versus supporting

Although the idea of transparent technology is similar in both *reproducing* and *supporting*, my reason to divide this into two different approaches is that microphones and loudspeakers are treated quite differently. For *supporting*, both microphones and loudspeakers are part of the instrument. Instruments often have their own loudspeaker (think of electric guitar amplifying systems), which results in at least as many loudspeakers on stage as there are instrumentalists. The loudspeaker is placed close to the sound-shaping component of the instrument, so that the sound comes from the same location as the instrument. Loudspeakers designed for *supporting* the sound of musical instruments do not respond as linearly as possible to all frequencies, but are tailored to respond in certain ways with certain frequencies. So-called guitar amplifiers are often a combination of an amplifier and several loudspeakers, designed to produce a specific sound. As careful as a player is in choosing the guitar, an amplifier is chosen as well due to its sound characteristics. Microphone use falling within the *supporting* approach category is also often adapted for the instrument: when used for support, they are often built into the instrument, as is the case with the pick-up for the electric guitar, for example. Instrumentalists and singers often have preferred microphones for amplification, chosen for the sound colour they add. In addition, the movements that singers make when using a microphone—closer or further from the mouth—could be analysed as an instrumental playing technique. Not only the level of amplification varies due to these changes in distance between mouth and microphone, but the sound colour does as well, depending on the characteristics of the microphone.

Contrary to the use of loudspeakers in the *supporting* approach, in the *reproducing* approach the loudspeaker systems should not be specialised for reproducing specific sounds, but be as flexible as possible, and ideally able to reproduce all kind of sounds at uniformly high quality. Identical loudspeakers might be used for reproducing instrumental settings as divergent as piano solo, jazz combo, pop band, or even an entire symphony orchestra. All this music can be listened to through the same loudspeaker pair in the living room. Even if the system is modified by changing to a 5.1 audio system, for example, the main approach remains: all music is listened to through one kind of loudspeaker set-up; no changes are required for different musical styles or instrument combinations. What these loudspeakers reproduce is a so-called phantom image of the musical performance, the "screen" on which sound is projected. In between the loudspeakers phantom sound sources[30] are placed: for example, a violin on the left and a violoncello on the right, whereas the viola sounds more towards the middle. To produce recordings whereby all kinds of music become playable through just one system, many different microphones are needed. The universal method found in the loudspeaker set-up for the *reproducing* approach is

[30] These sound sources are called phantom, as there are no real sound sources in between both loudspeakers. The sound seems to come from a certain direction, but this effect is in fact due to the mix of sound radiated by both loudspeakers.

not applicable to the use of microphones in this approach. The microphones are not part of the instrument, as they might be considered when used for the *supporting* approach, but their function could better be compared with that of an ear for each specific instrument. The sound of every single instrument is picked up by these "ears", often by using at least one microphone per instrument, and the microphone is chosen due to its specific characteristics and suitability for a particular instrument. Microphones are not only used specifically for certain instruments, but often some of them are also used for obtaining a so-called stereo image, an overview of the acoustic information of the performance. These microphones will produce phantom images of the recorded instruments in between the loudspeakers. The final recording is a mixdown of all these different, highly specialised "ears", reproduced on a universal loudspeaker system (Bartlett and Bartlett 2002).

Alterations in music due to sound reproduction technology

The *reproducing* and *supporting* approaches are both models for the possible relationships between microphones and loudspeakers, and musical instruments. The recording, intended as a reproduction of a concert experience, soon became an art form in itself. With continual attempts to create the perfect concert recording or transmission, better than one would ever be able to enjoy during a real concert, using all possibilities of the new technologies, the recording becomes a new way of perceiving music instead of a reproduction of a concert experience (Thompson 1995, 160). Attending a concert in your own living room becomes the ideal experience. What was meant to be a copy of a real experience has become superreal. Recordings are produced by combining many different fragments of several performances, so-called "takes". Even in alleged live recordings, various live takes are combined, and often the result is a performance that would not have been possible in a live concert situation. Mistakes can, for example, be cut out of a recording, resulting in an ideal interpretation of the piece. As Hans-Joachim Braun states: "improved sound reproduction technology has rather increased the difference between sound recording and sound reproduction than diminished it" (Braun 2002, 22).[31]

The same proves true in the case of the *supporting* approach. The development from acoustic to electric guitar is probably one of the best examples of how utilising amplification to support the sound of an instrument resulted in a completely new instrument (McSwain 2002). Another good

[31] As some argue, due to the "perfect" interpretations on recordings, concerts themselves have changed as well. It is no longer desirable for interpretation to contain spontaneous elements anymore, since the audience must recognise the piece according to the recording, which they had heard at home. "The reason that this streamlined performance comes to replace interpretation and its elements of spontaneity is precisely to ensure that the concert performance shall indeed be a copy of the record, and the concert-goer will not be disappointed" (Chanan 1995, 118).

example is the human voice. With the use of microphones on stage, the possibilities for singing were transformed, as I mentioned earlier. Singers no longer needed special singing techniques in order to fill a whole opera house. Speaking or even whispering could be utilised as elements of a voice performance. The practice of singing, therefore, changed enormously (for a more general discussion of this subject, see (Penman 2002) and (Lockheart 2003)).

Although numerous instruments changed owing to the introduction of microphones and loudspeakers, the *reproducing* and *supporting* approaches of microphone and loudspeaker use did not have a significant impact on the role of musical instruments in music. In fact, they even bolstered the conventional idea that music needs instruments and, in a certain sense, it even narrowed down the concept of what music and musical instruments could be. Recorded instruments often had to sound as closely as possible to the real musical instrument. The use of microphones and loudspeakers in music, and sound reproduction technology in general, was not developed in the first place to transform music, but rather to make music available to more people, especially in the private sphere of the living room (Freire and Palombini 2003, 67). The philosopher Theodor W. Adorno writes about the phonograph in his text *The Form of the Phonograph Record*: "The phonograph record is not good for much more than reproducing and storing a music deprived of its best dimension, a music, namely, that was already in existence before the phonograph record and is not significantly altered by it. There has been no development of phonographic composers" (Adorno 1990, 57). It is indeed remarkable that there was nearly no music developed especially for the phonograph or for the radio during the 1920s and 1930s, although many proposed this (see (Swainson 1931, 396) (Raven-Hart 1930, 138–139) and (Freire and Palombini 2003, 68)). The *Grammophonmusik*, composed by Paul Hindemith around the 1930s in Berlin, was an exception.[32] It was only after World War II that people such as Pierre Schaeffer* would compose with the use of gramophone records. An entire DJ and turntablist culture would emerge during the second half of the twentieth century, and working with reproduced music in general (often in the form of what is called "sampling" nowadays) would become a common phenomenon. I do think, though, that the fact that hardly any music was composed for the new sound devices, such as phonographs and radios, during the 1930s is another reason that these devices came to be considered less and less as belonging to the realm of musical instruments. Alterations in music composition itself, as related to the invention of sound reproduction technology, mainly commenced after World War II. The last two approaches I will discuss both did engender change in the relationship between musical instruments and music, in contrast to the *reproducing* and *supporting* approach.

[32] Paul Hindemith wrote a handful of pieces especially for the gramophone in 1930, but these initiatives never became more than random experiments (Katz 2004, 99–112).

Approach 3: generating

Around the 1950s, a new aesthetic attitude toward the use of microphones and loudspeakers in musical creation came into existence. The main aim of this approach was no longer to use microphones and loudspeakers simply for *reproducing* or *supporting* conventional musical instruments. On the contrary, this time the principal question was: what kind of music can only be heard or come into being through loudspeakers? What if an electrical signal, and no longer the movements of performers upon instruments, is taken as the starting point for sound?

The possibilities of new sound reproduction devices were regarded as promising for composers already before the Second World War. Many artists had been searching for new sounds during the first half of the twentieth century. They were looking for new material in music—not new as regards pitch or rhythm, but new in the realm of timbre. Composers as disparate as Kurt Weill and Edgard Varèse asked for a music that took into account the possibility of producing new sounds with the newly invented devices. Varèse wanted to have "a sound-*producing* machine instead of a sound-*reproducing* one" (cited in: (Freire and Palombini 2003, 68)), and Weill imagined "a host of new, unheard sounds that the microphone could produce in artificial ways if sound waves were raised or lowered, superimposed or interwoven, faded out or born anew" (cited in: (Freire and Palombini 2003, 69)).

Conventional musical instruments were no longer of any use in music invented with these new devices, as is described by Dorothy Swainson: "[Composers, CvE] may be able to eliminate interpreters altogether and write their music with a graving tool directly on to the wax with mathematical precision and certainty of obtaining the desired result regardless of whether their conception is producible on any known musical instruments or not" (Swainson 1931, 396). This idea relates to Riemann's idea that musical instruments are a mere means of transportation for musical ideas. Riemann and Swainson both see instruments as possible disruptions of the ideas of composers. Without needing musical instruments, the composer should be able to literally design, or sculpt, the sound he or she hears in his or her inner world. Konrad Boehmer claims that for an authentic electric music, "an uncoupling from the idea of an 'instrument'" (Boehmer 2004, 161) is needed.

This idea of creating music which no longer has any connection to existing musical instruments forms the third approach, which I term *generating*. The sound is produced by the loudspeakers and could not exist without them. A musical instrument is not present at all in this music. Whereas the sound of electronic instruments, such as the theremin, also need a loudspeaker to become audible, the difference lies not in the method of sound production, which may be the same (both are produced electronically) but rather in the acts of sound creation, which diverge.

The theremin is clearly a musical instrument, since the movements of the performer in order to control the sound are also audible (and of course visible as well) in the sounding result.

Whereas the examples of the *generating* approach are very rare before the Second World War, this approach began to flourish at the end of the 1940s and the beginning of the 1950s. Dick Raaijmakers* points out, that the composer has become a non-instrument-bound sound organiser,[33] a function which simply did not exist before. Conventionally, the instrument maker was inventing new instruments and therefore dealing with the relationship between music and technology. After the Second World War the composers themselves started to work with autonomous electronic sound (Raaijmakers 1990, 8-9). Karlheinz Stockhausen* was one of these composers, advocating new paths for music during the 1950s and claiming that composers should compose their own sounds instead of composing for sounds produced by already existing musical instruments. Stockhausen wanted to free music of what he calls the "dictatorship of the material" (Stockhausen 2004, 371), which was, for him, the sound of conventional instruments. In his eyes, compositions for piano, violin or clarinet could never be entirely new, invented from scratch, by the composer, since the timbre is predefined by these instruments. Timbre should become composable as well.

In his compositional technique, Stockhausen searched for a method to integrate "all the characteristics of the material into one uniform musical organization" (Stockhausen 2004, 372). According to him, characteristics of the material are pitch, loudness, duration and timbre. He aimed to use the same principle of organisation for all these characteristics. In applying serial composition techniques, the pitch and loudness of sounds could be organised rather easily in this way, but as long as one was composing with conventional musical instruments, this remained impossible with timbre. Pitch and loudness can be given a place in a hierarchy, from low to high and from soft to loud as well as scaled into all kind of divisions, by using, for example, microtonal distances. This, however, does not work for instrumental timbre, since a hierarchical arrangement cannot be effected within this domain, nor can an equal division of different timbres be devised. When considering timbre, there is no physically measurable equivalent of high and low or soft to loud: you cannot order the timbres of a piano, a violin and a clarinet in a mathematically meaningful row. But composers such as Stockhausen "wanted absolutely pure, controllable sounds without the subjective emotional influence of 'interpreters'" (Toop 1979, 380).

To compose timbre instead of relying on the timbre of conventional musical instruments, is possible if timbre is considered to be an addition of several pitches. To conceptualise a means of creating these fully-controllable sounds, I therefore take a brief look at one model for analysing

[33] My translation of "niet-instrument-gebonden klankorganisator".

and reproducing timbre. The sound of an instrument is dependent on its physical material and the way this material is brought into vibration. The material reacts to the energy input by vibrating. Specific patterns of vibrating create the so-called timbre or sound colour of the instrument. These vibrations of the material give rise to sound waves in the air. At the beginning of the nineteenth century, the mathematician and physicist Jean-Baptiste Fourier proved that every wave could be represented by a combination of a multitude of single-frequency waves, called sine waves. These single frequencies are what are normally called the partials of the frequency spectrum of a sound. This spectrum is changing over time, and so is the representation by sine waves. This model is important for composers interested in generating sound waves to be produced by loudspeakers, since it allows for the possibility to create complex sound waves from scratch.

A pure sine tone cannot be produced by any conventional musical instrument, since the physical material of the instrument vibrates with more than one single frequency.[34] With the invention of transducers for converting electricity into air pressure waves, an electric sine wave generator could be made audible through a loudspeaker, since a loudspeaker is generally designed to add the least possible of its "own" sound to the sound wave as represented by the electrical signal that drives the loudspeaker-coil's movements. When the loudspeaker is driven by an electrical signal in the form of a sine wave, the sound emitted by the loudspeaker will itself be very close to a sine wave. By adding together many sine tones, composers could have full control over the spectrum of the sound. This aggregation of sine tones became a very common technique in electronic music, and is usually described as additive synthesis. All manner of combinations unavailable in the frequency spectra of musical instruments could be tried out and, at least in theory, composers could entirely compose their own sounds.

Dead tones: music without movement

Conceptually, Stockhausen was strongly influenced by Karel Goeyvaerts*. As the musicologist Richard Toop argues, it was not Stockhausen who initiated the idea of composing sounds using sine tones, but Goeyvaerts, with whom Stockhausen had an intense correspondence during the early 1950s (Toop 1979, 386). Goeyvaerts produced several electronic compositions during this time. One of these pieces can be understood as revealing the core idea behind the *generating* approach: a music without any musicians should be made without any movements, even excluding the movements of tape. In Goeyvaerts' *compositie nr 4 met dode tonen*, the music is generated from nowhere. This piece exists only as a score, since it is a conceptual idea that

[34] The vibrations of tuning forks come quite close to producing a sine wave, as I will demonstrate in the next chapter.

cannot be transformed into sound.[35] Goeyvaerts had the idea of composing a music for what he called "dead tones". To compose dead tones, he imagined the following procedure: sine tones should be recorded while the tape recorder was in pause position. These sine tones should thus be recorded without any movement at all: even the tape machine should not move. The music would therefore be outside of time (Toop 1979, 387–388). The realisation of this composition is technically impossible, since sound is always happening in time: the perception of sound is a result of changing air pressure waves. These pressure waves are movements of air, and movement can only happen when one of the parameters is time.

We hear sound when air pressure waves, created by vibrating material, impact the membranes of our ears. These movements are all essential for the production and reception of sound. It is not possible to create sounding music without any movement, as Goeyvaerts' composition proves, but it is possible to create music without a performer and without musical instruments. Dick Raaijmakers* describes a goal of composing in terms of the *generating* approach: "to produce sounds that are by all means totally independent of any behaviour whatsoever of objects in nature" (Raaijmakers 2007, 435).[36] What must be avoided in this music is not all movement, but the inclusion of recognisable acts of sound creation. In the *generating* approach, semantic acts of sound creation should disappear. All articulation and timbre that reminds the listener of the cause of the sound should be erased. This is the material of the vibrating objects as well as the movements causing these objects to vibrate: a soft knock on a wooden object sounds completely different from a loud knock on the same object. As Stockhausen states:

> In general, one can already recognize a first criterion of quality in an electronic composition in the extent to which it is kept free of all instrumental or other sound associations. Such associations distract the listener's mind from the autonomy of each sound world presented to him, because he is reminded of bells, organs, birds or water-taps. […] Electronic music sounds best only as electronic music, which is to say that it includes as far as possible only sounds and sound relationships that are unique and free of associations, and that make us believe that we have never heard them before (Stockhausen 2004, 374).

Creating sounds without any association proved to be much more difficult, however, than developing a theory about them. But as was already the case with *reproducing* and *supporting*,

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[35] "Met dode tonen" is Dutch for "with dead tones". *Compositie nr. 4 met dode tonen* is an unrealised score of electronic music (Cross 1968, 53), since the idea is technically not realisable. During the 1970s, Goeyvaerts realised a modified version of this piece in the IPEM studio in Ghent, subsequently recorded on compact disc (D'Action 2008).

[36] My translation of "geluiden maken die uiteraard volledig los staan van welke gedragingen van objecten in de natuur dan ook" (Raaijmakers 2007, 435).

the same can be said here: the notional core of the approach is important, not the resulting product itself, which is, in this case, a practical realisation of a utopian idea.

Although in electro-acoustic music history Pierre Schaeffer* is often seen as the opponent of the ideas of the Cologne school, as concerns his view on musical instruments, he displays a very similar approach to that of Goeyvaerts and Stockhausen. Like these two composers, Schaeffer is also interested in creating a music that exists as pure sound only, without any references to musical instruments or other sound sources. Schaeffer developed his theory during the 1950s and 1960s. As a result of the invention of sound reproduction technologies, almost all sounds became available inside the concert hall. Schaeffer searched for a way to use any sound "purely for its own sake" as an "objet sonore", without associations to the source or to the meaning of the sound, as with spoken language (Schaeffer 2005, 65). He found a solution by cutting sounds into very short fragments. He cut the recorded sound at any point where a break in energy output occurred, a technique he termed "stress-articulation". The cause and meaning of the original sound becomes, in this way, unrecognisable. Recorded sounds originally produced by, for example, cars, an orchestra, a bird, or a human voice are all brought to the same level of "objet sonore" in this way. Compiling these different sounds into more extensive formations creates what Schaeffer calls "objets musicales", which then form the main elements of a composition.

The *generating* approach regards sound as the only component of music. Furthermore, the sounds that Goeyvaerts, Stockhausen and Schaeffer composed needed to be devoid of reference to the cause of the sound. A significant contrast in the music created in this manner, compared with that accomplished by the *reproducing* and *supporting* approach, is that in this case there is no sound at all without a loudspeaker. The music does not exist until the sound leaves the loudspeaker, contrary to the *reproducing* and *supporting* approach, in which case the music already exists before it leaves the loudspeakers, even before it enters the microphone. What is probably the most significant difference between these two first approaches and the *generating* approach is that for the first time in history, music was heard without the use of a musical instrument. Only the sound radiated by the loudspeaker came into existence, and what shaped the electrical signal that drove the loudspeaker became irrelevant. Whether it was air pressure waves caused by a physical object and picked up by a microphone or an electrical signal shaped

by an electric circuitry is unimportant, since the semantic acts of sound creation should not be recognisable in this music.[37]

Approach 4: interaction

In all three approaches explored up to now, the role of the microphones and loudspeakers is either to *reproduce* or *support* the interaction between musician and musical instrument, or, in the case of *generating*, to avoid anything similar to this kind of interaction. In all three approaches, however, microphones and loudspeakers are definitely not considered to be the musical instruments with which to interact. In the context of these three approaches, an object is identified as an instrument according to the recognisability of the interactions between performer and instrument, which result in musical sound. As the *generating* approach showed us, as soon as these interactions are no longer perceivable, a music without musical instruments can be generated. The opposite can probably also be contended: as soon as we perceive musical interactions between a performer and an object, we will perceive this object as a musical instrument. This *interaction* between performer and object is the fourth approach towards microphones and loudspeakers.

Resonance and resistance

To draw a conclusion from the previous paragraph, one could say that in order for microphones and loudspeakers themselves to be transformed into musical instruments, an interaction between these devices and performers must take place, with the intention to produce music. To come to a clearer idea of what kind of interaction I need to look for, I briefly investigate the interaction between what I call "conventional" musical instruments (such as violins and pianos) and their players.

Musical instruments are a vital part of music making and their characteristics have been developed and are co-created with the practice of which they form a part. The instrument reacts to the input of the musician. Regarding the relationship between players and conventional

[37] The *generating* approach includes many different ways of producing sound. It is out of the scope of my research to mention the different possibilities of sound production, but I would like to make one important differentiation. Electronic sounds can be generated and processed (whether their starting point is as air waves picked up by microphones or as electrical signals) in an analogue or in a digital form. The main difference between these two is that analogue synthesis still needs a specific "instrument" or "device" to produce a certain sound, whereas in digital technology there is no specific material set-up needed anymore. A computer can generate all kind of sounds, while using the same bytes (Weissberg 2010, 174).

musical instruments, a musical instrument, as with all other instruments, is often seen as an extension of the human body (Pelinski 2005). The instrument accomplishes a task initiated by the human body. The result of this task is sound to be heard by human beings. This sound comes into being owing to the vibration of a material, which generates air pressure waves. This material vibrates because energy is applied to it, which is largely mechanical energy, applied to the instrument by hitting it, submitting it to air pressure, or through other forms of friction, such as bowing. Often this energy comes from a human body, but it may also be supplied by machines (for example, air pumps in organs) or by nature (the wind in aeolian harps). It is obvious that this supply of energy is applied with an expected result. The musician hits, blows or strokes the instrument in a specific way, with the expectation of producing a certain sound.

I call this immediate connection between the body of the musician and the body of the instrument the "resonance" between them. The body of the musician excites the body of the instrument, which will resonate as a result of this excitation. His or her musical ideas become to sound through the body of the instrument. The musician needs the instrument to make the music sound and, at the same time, the instrument cannot sound without the body of the musician. Due to this close connection of both bodies, musicians often appear to be one with their instrument. Their musical ideas, what is happening in their minds, seem to be immediately expressed by the instrument.

This immediate connection between musician and musical instrument, as if the instrument is obeying all the wishes of the musician, is of course an illusion. Although, during a performance, the instrument might be perceived as being an extension of the body of the performer, this is the result of a long process. The performer has been communicating with the instrument for a long while—commonly called "practicing the instrument"—and has therefore learned how the instrument reacts to his or her actions. Every communication is mediated, since it is a transfer of content from oneself to another. And even prior to any expression, the idea has already been influenced by the instrument on which it will be played. The instrument forms the idea in the mind of the musician. As soon as a musical idea is played on an instrument, one will never be able to hear only the idea without the influence of the musical instrument. The instrument cannot be a neutral mediator, since one cannot subtract the instrument and retain the music. I would therefore say that the relation between musician and instrument is not only characterised by "resonance" but also by "resistance": the instrument does not always react to the actions of the musician in the intended way. The impossibility of playing every musical idea on every instrument is in fact an essential characteristic of a musical instrument. It is not endless possibilities but rather the finiteness of these possibilities which render an instrument fruitful for music-making: "But a musical instrument is no mere means: it does not disappear in its use. The musical instrument remains opaque and one does not know how it will respond to a given gesture" (Evens 2005, 83). Clearly, this position is the antithesis to what was claimed by

Riemann, who saw a musical instrument as a mere means for transplanting the ideas of a composer into the heads of the audience.

Whereas playing a glissando on a trombone is relatively easy, a true glissando is impossible to play on the piano. Musical instruments resist the realisation of many musical ideas, even when played by a skilled musician. The possibilities of musical instruments have borders, and although these borders may be extendable, they cannot be dissolved completely. The musician often explores these borders: "The instrument resists the creative impulse, pushes back against the musician, problematising her desire and forcing her to make tactical manoeuvres, right there where the music is happening" (Evens 2005, 162).

The development of most instruments can be seen as a process: the *interaction* between a musician and an instrument results in either discovering new playing (*interacting*) techniques or in changing the musical instrument itself. Looking at the three approaches mentioned above—*reproducing*, *supporting* and *generating*—microphones and loudspeakers have not been developed as the result of any form of *interaction* between them and musicians. For the *reproducing*, *supporting* and *generating* approach, the most desirable feature of microphones and loudspeakers is to display the least resistance possible: they should never be heard creating semantic acts of sound production. Not having any resistance at all, being just a transparent device open to all sounds, would mean that they cannot be considered a musical instrument.

Transforming objects into musical instruments

Now that I have analysed the *interaction* between a conventional instrument and its performer, I will look briefly at a possible interaction between a performer and a non-musical object. Objects that are normally not considered to be musical instruments must be brought by the artist into the realm of musical instruments. Pushing a CD player's play button in the customary way is not regarded as an interaction between performer and musical instrument. But one might imagine a piece of music in which this interaction becomes essential and in that case, the CD player would become a musical instrument. Imagine a piece of music in which the performer is not only pushing the play button of the CD player on and off but is also choosing different tracks and using the fast forward button. And we do not have to only imagine this, since there are plenty of examples that demonstrate the use of a CD player and CDs as musical instruments, such as, for example, *Music for Two CD Players* (1986) by Yasunao Tone (see (Straebel 2009, 25–28) and (Kelly 2009, 210-283) for a general overview on compositions for CDs and CD-players).

Using these kinds of musical interactions, objects can be transformed into musical instruments. The necessary treatment in order for these objects to be perceived as instruments would be to

interact with them in such a way that results in music. It is in this way that all kinds of non-musical instrument objects (turntables, radios, laptops, spoons, bikes and wine glasses) can be transformed into musical instruments. I will explore different kinds of *interactions* between performers and microphones and loudspeakers further in chapter 4.

Finding the resonance and resistance of microphones and loudspeakers

As I pointed out in my analysis above, these four approaches towards the use of microphones and loudspeakers (*reproducing*, *supporting*, *generating* and *interacting*) should be regarded as theoretical models and not as fully realisable or realised practices. Truly transparent uses of microphones and loudspeakers—as is the ideal in the *reproducing*, *supporting* and *generating* approach—do not exist. "The technology of music production, recording and reproduction [...] operates in a metaphorical world, one that is parallel but not equivalent to human experience" (Poss 1998, 46). As soon as these models are applied in practice, they will deviate from these ideal claims, as I highlighted when describing the changes in singing and the construction of the electric guitar. The unattainable aspects of these approaches lead to new ways of exploring music, however, and are therefore valuable as well. Instead of focusing on the transparent aspect of microphones and loudspeakers as do the other three, the fourth approach of *interacting* focuses on the opaque character of the musical instrument. The emphasis is on microphones and loudspeakers and their own innate possibilities of *interactive* sound creation.

Although built to transmit the vibrations produced by other objects, microphones and loudspeakers are themselves made from physical material. To discover their qualities as musical instruments, I need to force them to make their own material perceptible and discover the resonance and resistance that arise when *interacting* with this material. The sound should be shaped by the physical presence of the microphones and loudspeakers themselves. Microphones and loudspeakers should take over the semantic aspect of the sound production instead of remaining as transparent as possible. In the next chapter I will investigate the sound that can be produced through approaching microphones and loudspeakers as musical instruments and how microphones and loudspeakers "lost" their own sound and became "transparent" devices. What kind of *interaction* might possibly take place between the performer and the instrument "microphone-loudspeaker" will be the question explored in chapter 4.