Playing "Air Instruments": Mimicry of Sound-producing Gestures by Novices and Experts

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Abstract. Both musicians and non-musicians can often be seen making sound-producing gestures in the air without touching any real instruments. Such "air playing" can be regarded as an expression of how people perceive and imagine music, and studying the relationships between these gestures and sound might contribute to our knowledge of how gestures help structure our experience of music.

1 Introduction

With the exception of "classical music" contexts, where it is generally considered taboo for listeners to make movements during public performances, listeners often spontaneously move their bodies, e.g. dance, tap their feet, nod their heads, make gestures with fingers, hands, and arms, etc. One category of such movements is known as playing "air instruments", e.g. "air guitar", "air drums", and "air piano", meaning making sound-producing gestures without making physical contact with any instrument, hence playing "in the air". Often done in private or semi-private settings (e.g. a pianist "playing" through a piece of music when trying to recall it, or someone making an air drum performance to the music at a party), some people also take the performance of air instruments very seriously. This is apparent in national and international air guitar championships, where the mimicry of sound-producing gestures (as well as other movements and expressions) is developed to high levels of sophistication.

Besides demonstrating strong personal involvement with the music, we believe air instrument playing shows some important principles of the mental coding of musical sound for non-musicians (novices) and musicians (experts) alike. We believe that images of sound-producing gestures are an integral part of the perception of musical sound, i.e. of identifying, discriminating, grouping, or doing "auditory scene analysis" [1] of musical sound, as well as of remembering, recalling and imagining musical sound, i.e. of musical imagery [2]. In taking air playing seriously, we assume that what can be observed of *overt behavior*, also reflects some essential features of *covert mental images* associated with musical experience.

When observing people playing air instruments, distinctions between sound-producing gestures and other kinds of gestures may not always be so clear-cut. Initially, we define *sound-producing gestures* as human movements made with the intention of transferring energy from the body to an instrument, i.e. as *excitatory gestures*, as well as human movements made with the intention of modifying the resonant features of an instrument, i.e. as *modulatory gestures* [3]. We have excitatory gestures such as hitting, stroking, bowing, blowing, kicking, etc., and modulatory gestures such as shaking, flexing, deforming or moving a mute. Furthermore, these gestures can have various *modes of execution*, such as fast, slow, hard, soft, short, long, etc., evident in several music-related metaphors (e.g. "hammering", "sweeping", "caressing"). These various modes of execution are often associated with what we like to call *amodal, affective or emotive gestures*, which may potentially include all the movements and/or mental images of movements associated with more global sensations of the music, such as images of effort, velocity, impatience, unrest, calm, anger, etc. In observing air instrument playing, such amodal, affective or emotive gestures often tend to fuse with sound-producing gestures in the more strict sense (i.e. excitatory and/or modulatory gestures). In some cases of air playing we may also see more vague *sound-tracing gestures*, such as in following melodic contours, rhythmical/textural patterns or timbral/dynamical evolutions with hands, arms, torso, or whole body. Such gestures could be understood as reflecting the total sonic evolution of the music more than the assumed sound-producing gestures (see [4] for a more extensive discussion of gesture categories).

Air playing gestures may often be quite approximate or sketch-like, posing several theoretical and methodological challenges (see sections 4 and 5 below), but this vague, and inexact nature of air playing is also what we find so intriguing. Observing how even novices make spontaneous air playing gestures which largely match the music, makes us believe that there are important links between musical sound and gestures in need of serious study. In the following sections we will present some theoretical considerations, an account of observation studies we have carried out, and some remarks on how we understand air playing in the context of music cognition.

2 Auditory-gesture links

For trained musicians, the link between sounds and sound-producing gestures are in most cases immediate and even involuntary [5]. Most musicians will probably agree that making, or merely imagining, sound-producing gestures is an efficient strategy for recalling music, or even planning and carrying out musical improvisation [6]. From such practical accounts, as well as from some experimental evidence [7], it seems reasonable to claim that musical memory includes procedural memory, i.e. memory for gestures, as well as auditory memory, i.e. memory for sound. However, we believe there are more general reasons for the close auditory-gesture links that we are studying here.

From an "ecological" perspective, it seems quite clear that auditory perception makes use of a number of cues and experience-based schemata when trying to make sense of sound. In particular, identification of sound source, what Bregman calls *stream segregation* [1], is important for making sense of the complex mass of sounds that we are exposed to. Sounds are associated with causality, hence with both sound-producing actions and resonating objects. As for resonating objects, such as strings, tubes, plates, membranes, etc., we seem to posses a considerable amount of "everyday" knowledge of features associated with various materials and shapes, e.g. "metallic", "soft", "hard", "hollow", etc. Likewise, we seem to have extensive ecological knowledge of the excitatory and modulatory gestures used to generate sounds [8].

One of the most significant efforts to explore auditory-gesture links can be found in the so-called "motor theory" of perception in linguistics [9, 10]. This theory has claimed that language perception, as well as language acquisition, is based on learning the articulatory gestures of the human vocal apparatus. In other words: we can make sense out of what we hear because we guess how the sounds are produced. Although this motor theory has been controversial, recent neuro-imaging studies seem to support the idea of perception as an active process involving motor cognition [11, 12]. There have also been suggestions of close evolutionary links between speech sounds and gestures [13], and research on gestures in speech contexts suggests that gestures not only are supplementary to the verbal content, i.e. an element for added expression and emphasis [14], but also instrumental in facilitating or even generating speech [15]. Lastly, we believe ideas from recent neuro-cognitive research on motor elements in perception and cognition in general [16], fit quite well with the idea that there are close links between sound and gestures. This neuro-cognitive research suggests that we regard perception and cognition as an incessant simulation and re-enactment of our impressions of the external world and of our bodies, implying that a mental "re-play" of sound-producing gestures would be part of making sense of sound.

3 Motormimetic sketching

Combining the term *motormimetic*, denoting the imitation of "real" sound-producing gestures, and *sketching*, indicating the approximate nature of the imitation, we end up with the expression *motormimetic sketching*. Motormimetic sketching can be an activity of both novices and experts, generating quite approximate, yet in our opinion, significant images of musical objects.

Imitating what we believe others are doing, either overtly or covertly, is increasingly regarded as fundamental not only to learning and socialization, but also for understanding what others are doing [17, 18]. Covert imitation is understood to be at work whenever we see and/or hear others acting (although, in some cases, children, as well as people with some mental disorders, may exhibit overt imitation). Imitation, understood as a persistent activity when perceiving the actions of others, seems to go quite well with the abovementioned motor theory of perception, i.e. that we mentally simulate the actions of others when we are trying to make sense of the sounds they make.

Air instrument playing, understood as motormimetic sketching, is then an egocentric, "I do" type of activity, imitating assumed sound-producing gestures of even quite complex musical objects, and also by people who would in no way be able to reproduce the heard music on an instrument. Thus, we speak of a *novice to expert continuum* in this motormimetic sketching, as opposed to a more sharp distinction we would make between people unable, and people able, to play "real" instruments. One objective of our studies is to explore these approximate renderings of sound-producing gestures by novices, as we believe this could teach us something about how people who do not have any musical training (and who even regard themselves as "unmusical") perceive significant global features in the music they hear.

As for the phenomenon of sketching, we were surprised to find so little research within the cognitive sciences that dealt with this subject. The most relevant discussions of sketching we have found are either in more art-oriented [19] or in design-oriented literature[20]. As we know from sketching in the visual arts, we may find a sketch quite salient, and well representing what it is supposed to depict, in spite of the rather sparse number of pencil strokes. We may thus speak of sketching, in the context of gestures, as a kind of "goal-directed imitation", what is called GOADI in [21], meaning that people (both children and adults) seems to initially focus on some goal-points when imitating gestures.

In our context, we understand the phenomenon of motormimetic sketching as follows: On first listening, we can make a spontaneous and quick tracing of assumed sound-producing gestures, reflecting the rough outline and global feeling (mood, sense of effort, sense of speed, etc.) of the music. Subsequent listening will help in gradually refining and adding detail, but the overall shape and character is usually manifest in the course of the first listening. In this way, motormimetic sketching is a kind of top-down activity, as the overall shapes of the gestures may set the frames for progressively finer details in the air playing.

4 Observation studies of air piano playing

To find out more about motormimetic sketching as a phenomenon, as well as some associated theoretical and methodological issues, we conducted a series of observation studies of air piano playing.

Subjects and sessions. Five persons with different musical and movement-related training were recruited for the observation studies:

A. Novice. No musical or movement-related training.
B. Intermediate. Some musical training on different instruments, and some movement-related training.
C. Semi-expert. Extensive musical training on several instruments and university level music studies, but no movement-related training.
D. Semi-expert. Extensive musical training on piano and university level music studies, but no movement-related training.

E. Expert. Professional pianist with extensive university level training in performance, but no movement-related training.

All subjects were informed about the purpose of the study, as well as how the sessions were going to be conducted. This included explicit instructions about trying as best they could to play air piano, by focusing their attention towards making what they believed to be the sound-producing gestures best fitted to the music they were going to hear. They were also told that the musical excerpts might or might not be familiar to them, and that their initial air playing gestures probably would come *after* the corresponding sounds, but as each excerpt would be played three times, they would be able to adjust their gestures with each repetition. The subjects were not allowed to see each other's performance, and only one subject and the authors were present in the studio during each recording session.

The sessions took place at the *Intermedia* video studio at the University of Oslo, featuring a blue screen background and high quality DV cameras. The cameras were placed in front and to the right of the subjects, at a distance of 4 meters. Firewire web-cams placed in the same positions allowed for rudimentary realtime video analysis, but it is the recordings from the DV-tapes that have been the source for our analysis.

Musical material. The musical material used for the studies were excerpts of piano music covering various playing techniques and styles:

1. Opening from Chopin's Scherzo no. 2 in Bb minor op. 31 (17 seconds) [22].
2. Opening from Scriabin's Sonata no. 5 op. 53 (10 seconds) [23].
3. Opening from the third movement of Beethoven's 3rd Piano Concerto (16 seconds) [24].
4. Opening from Messiaen's Regard des Anges from Vingt regards sur l'enfant Jesus (22 seconds) [25].
5. Excerpt from Tokyo 84 Encore by Keith Jarrett (16 seconds) [26].

The excerpts were chosen so as to present different features such as large pitch-space, salient phrases and attacks (excerpts 1 and 2), periodic and distinct textures (excerpt 3), percussive and dense textures (excerpt 4), and more groove-based types of textures (excerpt 5). The music was taken from commercially available CDs and DVDs, and recorded on one continuous track to facilitate playback and analysis. Each excerpt was repeated three times with 2 seconds of silence between similar excerpts and 5 seconds of silence before new excerpts.

Data display and analysis. The approximate nature of air playing (no keys to hit or miss, no fixed spatial coordinates), and the complexity of the gestures, makes it a formidable challenge to make reasonably well-founded judgments and analysis. Finding exact positions of hands and fingers in 3D from our video recordings seemed too difficult, and not particularly interesting, at this stage. Instead, we decided on an "eyes and ears" based annotation process.

As an aid in analysing the video material, we have developed the *Musical Gestures Toolbox*[1], a collection of patches built with the graphical music pro-

[1] A beta-version is available at http://musicalgestures.uio.no

gramming environment Max/MSP/Jitter [27]. Starting as a simple playback tool for video files, with image adjustments, rotation and zooming, it has grown to also include various types of motion-based analysis, sound analysis, preservation of musical pitch when changing playback speed, "posture"-recognition (figure 1), and automatic cropping. The latter function is particularly useful since it allows us to easily focus on various parts of the body, for example only the head or the hands. Also included are possibilities for saving snapshots and image sequences of the video stream (figure 2), and making comparative analysis of several video files (3).

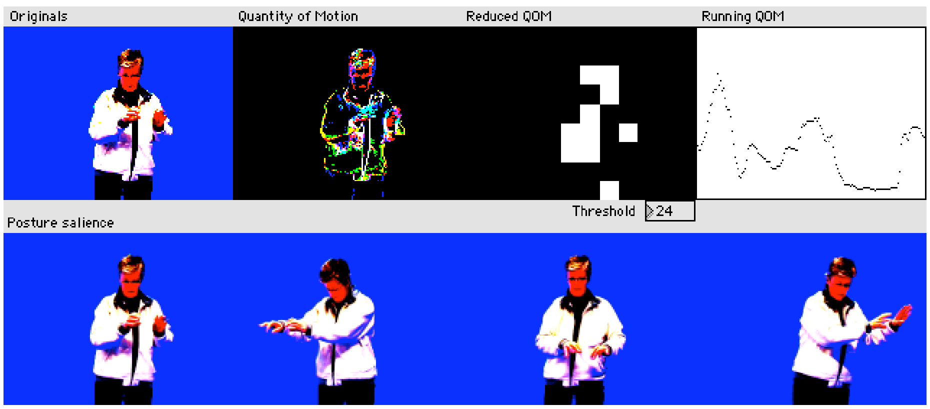

Fig. 1. Output of a patch made for storing an image every time the change in quantity of motion goes above a certain threshold. The original video stream and quantity of motion images in the top row, and the last four saved images below

Also, using the *EyesWeb Motion Analysis Library*[2], we have looked at different types of movement features, such as the *silhouette motion image* (SMI) feature which creates trails of recent movements, and is an efficient tool for simulating the effect of short-term memory for trajectories, enhancing (or exaggerating) the contours of movements. A decay function allows for variable lengths of "lingering" and is useful for seeing gestures of pitch contours as well as accents (size of attack movements).

We have experimented with various other data collection techniques for gestures such as flex sensors, accelerometers, digitizing tablets, etc. but feel that the main challenge for the moment is to develop a better conceptual apparatus for dealing with sound-producing gestures and sound. Both gestures and sounds are continuous, yet making sense of gestures and sounds alike requires chunking continuous streams into units. Hence, conceptually we have a fundamental duality of the continuous and the discontinuous which we, for the moment, have simplified to a duality of *trajectories* and *postures*. Both elements can give us important

[2] See http://www.eyesweb.org for more information

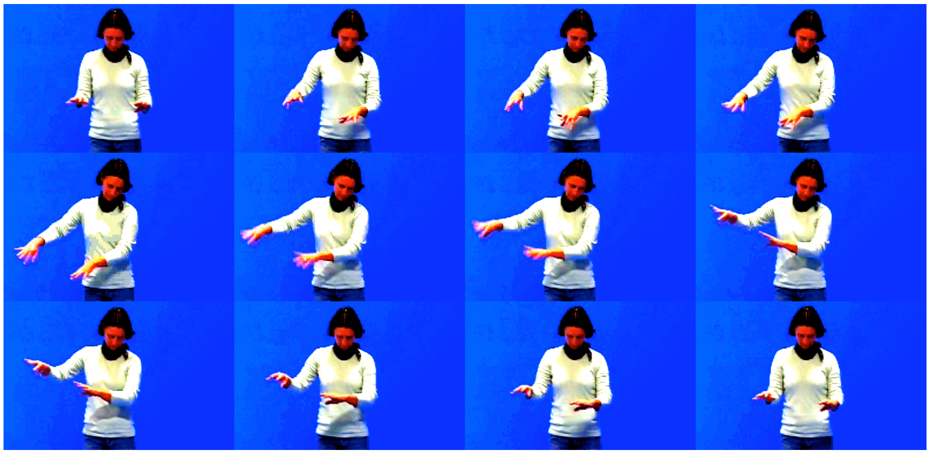

Fig. 2. Novice performer playing upward scales in the Scriabin excerpt. Although quite approximate, this example shows that there is a relatively good pitch-space to imagined keyboard correspondence (sequence running left to right, top row to bottom row)

Fig. 3. Output of a patch made for comparative analysis of three separate air piano performances, showing a novice, semi-expert and expert performer from left to right. The quantity of motion images with bounding boxes, are very useful when the movements are so subtle that they are difficult to see in the original video

insights on gestures, as can be seen from figure 2 where the continuous trajectory is broken down into a series of snapshots. The postures can be understood as goal-points [21], i.e. as important points for evaluating the correspondence between sound-producing gestures and sound-events.

5 Gestural correspondences

In evaluating air piano performances, we have taken as point of departure *the minimum necessary real sound-producing gestures by any pianist to generate the sound heard in the excerpts*. This means simply that in any real performance (i.e. not air performance) of the excerpts, keys have to be depressed by fingers in order to produce the sounds, and hands/arms have to move in order to position fingers so that they can depress the right keys. We use the term *correspondence* here to denote the relationship between what we can observe in the air playing and what would be the minimum movements necessary for any real performance of the excerpts. All correspondences we refer here are based on our subjects' fingers/hands/arms movements along an imagined keyboard (i.e. the horizontal axis) and onset motions by fingers/hands/arms (i.e. the vertical axis), and are ordered into the 7 categories of table 1.

In evaluating the air piano performances, we should note that although the subjects, prior to the video recording sessions, all stated that they understood the intentions of our air playing study, it is of course an open question to what extent they themselves would distinguish between sound-producing gestures and other more unspecific, yet music-related gestures such as head, torso, or whole body movements. It should also be noted that the lack of force feedback in air playing may have been awkward to some of the subjects, meaning that they would make different gestures playing air piano than they would playing the real thing.

Considering the intrinsically approximate nature of air playing, as well as the great difficulties we would have with a machine-based registration of sound-producing gestures mentioned earlier, we have chosen to give approximate, qualitative labels to the different degrees of correspondence between sounds and gestures that we have been able to observe. Using the various viewing tools mentioned in the previous section, we have carefully studied all the video recordings of the air playing gestures of our five subjects across the five different excerpts, but with the main focus on the last repetition of each excerpt (i.e. when the subjects had become most familiar with the music). By making detailed annotations, event-by-event, chunk-by-chunk, within each excerpt, we believe we have a fairly broad, distributed basis for our correspondence judgments. In making these judgments, we have also had a high degree of consensus amongst us (the authors).

We have chosen the following labels, and for convenience, assigned relative score values to the labels, to denote degrees of correspondence between air playing gestures and required real gestures:

– *No correspondence*, score value = 0, meaning the required sound-producing gestures are not visible.
– *Poor correspondence*, score value = 1, meaning the required sound-producing gestures are barely visible.
– *Approximate correspondence*, score value = 2, meaning the required sound-producing gestures are clearly visible, but inexact or wrong with regards to details.
– *Good correspondence*, score value = 3, meaning the required sound-producing gestures are clearly present and also match quite well in details.

Although these score values represent qualitative judgments of correspondences, we have for the sake of comparison calculated simple averages for each subject across the five excerpts used in our observation studies here, in order to make the summary of correspondences in table 1. It should be remembered that the five excerpts used were quite dissimilar, and they were deliberately chosen to expose the subjects to a variety of sound-producing gestures. Yet, there is still a fairly consistent level of performance by each of the subjects across the excerpts, seldom resulting in greater correspondence degree differences than 1.

Table 1. Correspondences of observable air playing gestures by all subjects (A–E), on a scale from 0–3, where 3 is good correspondence with the music. See text for details

	Feature	A	B	C	D	E
1.	Overall activity correspondence, i.e. *density of gestures in relation to density of onsets in the music*, but regardless pitch and onset precision	1.4	1.8	2.6	2.6	3
2.	Coarse pitch-space/keyboard-space correspondence, i.e. *relative locations of hands left-to-right on an imagined keyboard at phrase/section level*	0.8	1.4	2.0	2.4	2.8
3.	Detail pitch-space/keyboard-space correspondence, i.e. *relative locations of fingers on an imagined keyboard at note-by-note level*	0.2	0.6	0.8	1.6	2.4
4.	Coarse onset correspondence, i.e. *synchrony at downbeat or event level* (event in stead of downbeat in cases of less or non-periodic music)	1.6	1.4	1.8	2.6	2.6
5.	Detail onset correspondence, i.e. *synchrony of finger and/or hand movements at note-to-note level*	1.0	0.2	0.8	1.8	2.2
6.	Dynamics correspondence, i.e. *size and speed of hands/arms/body gestures in relation to loudness*	1.0	0.8	2.2	2.8	2.8
7.	Articulation correspondence, i.e. *movements for accents, staccato, legato*, etc.	0.2	0.2	0.8	1.8	2.4

As for the categories we have designated here, the idea was to proceed from global to more detailed correspondences. Hence, in table 1, we start out with the overall activity correspondence, followed by pitch, onset, dynamics and articulation correspondences, hoping that this ordering should be informative as to how different levels of expertise are manifest in different aspects of air playing.

Category 1 concerns the overall activity correspondence, i.e. *the density of gestures in relation to the density of onsets in the music*, but regardless precision in onset-synchrony and pitch-space. This is a very coarse indication of the overall gestural activity in the air playing, and reflects the general or global impression of activity in the music such as *agitated*, *calm*, *fast*, *slow*, etc. Sometimes we could for example see a flurry of finger movements accompanying rapid, note-dense passages, which will give a rather good correspondence judgment for overall activity, but poor values in terms of detail pitch and onset-synchrony. Interestingly, novices scored relatively well in this category.

The next two categories concern relative pitch-space correspondences. Category 2 indicates the *coarse* pitch-space to keyboard-space correspondence, i.e. *relative locations of hands left-to-right on an imagined keyboard at phrase/section level*. This implies a spatial resolution along the imagined keyboard at the octaves level, and reflects the relative register in relation to the entire piano keyboard at any given time. Some of the excerpts (Chopin, Scriabin, and Messiaen) were chosen for (amongst other features) this prominent use of large registers, and we can see that both novices and experts scored relatively well on this correspondence. However, with category 3, where the focus is on detail pitch-space to keyboard-space correspondence, i.e. *relative locations of fingers on an imagined keyboard at note-by-note level* (in most cases roughly within the octave ambit), we see that novices scored relatively lower than in categories 1 and 2, as did the experts, but relatively less so.

For onsets, we have made a similar distinction between coarse and detail correspondences. Category 4 indicates coarse onset correspondence, i.e. *synchrony at downbeat or event level* ("event" instead of downbeat in cases of less or non-periodic music, e.g. the Chopin, Scriabin, and Messiaen excerpts). The correspondence is relatively good for novices and experts alike, something we attribute to the salience of certain events in the Chopin, Scriabin, and Messiaen excerpts, and to the clear periodic nature of the Beethoven and Jarrett excerpts. As was the case for the pitch correspondences, the category 5 detail onset correspondence, i.e. *synchrony of finger and/or hand movements at note-to-note level*, shows on the whole less good correspondence than category 4 for both novices and experts.

Lastly, we were also interested in correspondences regarding dynamics and articulation. In category 6, we were looking for dynamics correspondence, i.e. *size and speed of hands/arms/body gestures in relation to loudness*, something that we believe is relatively well reflected in the gestures of both novices and experts. However, with category 7, articulation correspondence, i.e. *articulation movements for accents, staccato, legato*, etc., novices did not show much, but the experts tended to be quite clear about these kinds of movements.

Since the values in table 1 are based on qualitative judgments, and since we only had 5 subjects in this pilot study, we are reluctant to make more extensive correlation processing of these values. However, it seems reasonable to conclude that there is a continuum from novice to expert regarding overall, coarse correspondences between the music and sound-producing gestures: Novices clearly seem to perceive and make the corresponding gestures here. But for details in pitch, onsets, and articulations, i.e. what we would consider textural detail, novices seemed to make less and more inaccurate corresponding gestures.

6 Conclusions and further research

We understand air playing as motormimetic sketching, meaning that air playing includes the twin components of *imitative gestures* and *sketching*. Imitating the gestures of others, in our case the innumerable gestures of musicians playing which we have seen throughout our lives, seems to be a resource for making sense of sounds. Although imitating sound-producing gestures may be a kind of "tacit" knowledge, we believe it is a resource that could be more actively exploited in both musicology and in various practical activities such as performance, composition, improvisation, and music education. However, this would require to acknowledge the value of sketching, i.e. of approximate, vague, "incorrect" gestures. This means to understand these gestural sketches as appropriate and useful global images of music, as playing an important role in parsing and chunking musical sound, as well as in grasping rhythmical, textural, melodic, and harmonic patterns. We thus believe it is a good idea to continue exploring air playing, as well as other sound tracing gestures. To do so, we also have to work towards the following:

- Enhanced means for gesture tracking, hopefully providing us with useful machine-generated data on movement trajectories.
- Enhanced conceptual and technical means for representing gesture trajectories and correlating these with sound.
- Better understanding of multimodal integration, in particular the neurocognitive bases for gesture-sound relationships.

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