Musical Gestures: An Empirical Study Exploring Associations between Dynamically Changing Sound Parameters of Granular Synthesis with Hand Movements

Eirini- Chrysovalantou Meimaridou[1], George Athanasopoulos[2] and Emilios Cambouropoulos[3]

[1] Department of Music Studies, Aristotle University of Thessaloniki, Greece
(eirini.meimaridou@gmail.com)
[2] Durham University, United Kingdom (georgios.athanasopoulos@durham.ac.uk)
[3] Department of Music Studies, Aristotle University of Thessaloniki, Greece
(emilios@mus.auth.gr)

Abstract: This study explores the relationship between music and movement, focusing on hand movements in relation to electronically produced sound events (granular synthesis). This relation is studied empirically by presenting pairs of hand and sound gestures (in the form of videos) to participants, while trying to find cases where correlations exist between the two. More specifically, the focus is on properties of sound such as pitch, density and dispersion (in the context of granular synthesis), as well as on their association and description through hand gestures. A complementary goal is to examine whether any correlations exist between the properties of the hand movements (kinetic velocity, direction or surface) to the sound characteristics mentioned above. 48 participants (F: 29; R: 21-34) were asked to rate the goodness of fit between hand gestures and accompanying sound events. Participant responses confirm findings from previous studies, while new interesting observations, such as the connection between sound dispersion and kinetic energy of motion, are noted.

Keywords: Gestures, Musical Gestures, Embodied Music Cognition, Sound and Movement Correlations, Granular Synthesis.

1 Introduction

1.1 Musical Gestures - Music and Sound Associations

Recent years have seen an increased interest in investigating the association of music with non-musical concepts, especially with bodily motion. The human body "can be considered as the mediator between the person's environment and the person's subjective experience of that environment" [1, p. 5].

Undoubtedly, gestures often contribute to social interaction, facilitating communication and the attribution of meaning by means of hand movement [2]. During a musical experience, the human body interacts with music, and the human mind deals with the creation of interpretations related to this physical interaction [3]. Musical gestures involve the understanding of body, mind and environment, and their study is part of embodied music cognition [4]. Musical gestures may refer to a variety of possible actions with different functionalities: they may produce a sound, serve communication or, as it will be examined in this study, they may "describe", accompany or illustrate a sound event [2].

Music and movement are two concepts that interact and function supportively for each other; consequently, musical gestures are among the visible manifestations of this relationship. As a result, listening to a sound often leads people to creating correlations with concepts such as shape, material, size, direction, but also more abstract information such as colors or feelings [5].

People tend to associate various sound characteristics with physical space and movement, and consequently with musical gestures [6]. Sound features such as pitch and dynamics can be described as changes in the type, direction, or speed of a movement that accompanies them. Beyond that, gestures facilitate music understanding and music expression and are an important issue in the field of musical research [7].

On the one hand, the associations of music and movement rely on inherent tendencies and unconscious processes [8]. On the other hand, musical gestures may be influenced by numerous factors that emanate from a person's environment. "Although every music listener has a body, every culture constructs the human body differently" [8, p. 388]. Consequently, the performance of musical gestures is linked with social and cultural characteristics, such as language and music education [6], [8].

1.2 Related Work

As outlined in the previous section, people tend to "embody" sound and associate auditory stimuli with images, shapes or metaphors (kinetic or not). This section focuses on previous studies and findings that were the starting point for our research hypotheses.

Pitch is one of the most investigated music parameters in the context of sound and movement association. The most frequent and thoroughly examined correlation is the one concerning pitch and the vertical axis, and generally the notion of "height" [6], [9]. This is one relation between sound and movement examined in this study.

In addition, the present study explores the concept of constancy and its correlation with musical gestures. Here, the term 'constant' refers to an auditory stimulus that does not change during its evolution in time. According to the literature, the majority of people tend to associate time continuity with the horizontal x-axis [10] and with a left to right direction [11]. Another interesting finding is that the "description" of a sound with constant pitch, may guide people to the cessation of a producing action that accompanies the auditory stimulus [9]. The present study investigates how a gestural representation of a constant sound may be perceived when the x- axis is absent from the participants' choices.

As the auditory stimuli of this study concern sounds generated through granular synthesis, it was considered plausible to investigate some of the control parameters of this technique. Our interest turned to the concept of grain density and how it may be associated with (hand) gestures. Since the term tempo means the number of beats in a unit of time, and the term density means the number of grains in a unit of time, these concepts may show common trends, e.g. when associating sounds and motion. Tempo has been correlated with the concept of speed in previous research [6], so we hypothesize that density may also be described by this term. Additionally, we observed that two-dimensional graphic representations of grains (introduced by Ianis Xenakis), illustrate how different numbers of grains (and different density levels) can be represented in a delimited surface [12]. These findings prompted us to explore associations between density and speed movement or surface of movement. Since no previously published study has examined the possible relationship between sound dispersion (another control parameter of granular synthesis) and motion, we attempted to examine the correlation of dispersion with the term of speed and kinetic energy.

Finally, when people associate certain auditory stimuli with movement, the gestures they make evolve in time in a similar manner as the sounds do. This means that intensifying changes in sounds trigger corresponding kinetic intensifications, while musical abatements encourage motions with decreasing intensity [6].

1.3 Hypotheses

Based on the literature reviewed above, our hypotheses regarding the participants' responses are the following:

i. A constant sound (where density, dispersion and pitch of sound grains remain unaltered) will be associated with a motionless gesture.

ii. Modifications in grain density of the sonic stimuli will be linked to modifications in the surface of moving visual stimuli.

iii. Changes in grain dispersion of the sonic stimuli will be associated with changes of the hand gesture's kinetic energy and velocity of finger movement.

iv. Changes in pitch will be linked with changes of movement on the vertical axis

v. Opposite pairs of sound stimuli (increase and decrease in the density/ dispersion/ pitch) will be associated with opposite pairs of hand gestures (increase and decrease of movement's surface/ kinetic energy and velocity/ upward and downward gesture on y-axis).

2 Materials and Methods

2.1 Participants

The survey involved a random sample of people of diverse age, gender and musical knowledge background. In total, 48 people (F: 29; R: 21-34yrs, 27 self-identified musicians) participated in our study. Among the musicians, 23 participants were undergraduate or postgraduate university students majoring in music, while four were studying music at accredited conservatories for at least ten years. 14 musicians were trained as pianists, while the others were percussionists or string performers. The average duration of active music engagement was fourteen years.

2.2 Auditory Stimuli

Eight auditory stimuli (see Table 1) were synthesized using granular synthesis (Granulab VST 2 version)[1]. Among the granular synthesis parameters available, density, dispersion (grains within certain pitch range) and pitch were selected for further

[1] Granulab Inc. "Home". [Website] https://www.abc.se/~re/GranuLab/Granny.html

exploration. All stimuli were six seconds long and all alternations from the initial to the final state were linear and regular within this time span.

Table 1. Detailed Description of Sound Data

No	**Sound Parameter**	**Description**	**Duration**	**Alterations**		
				Density	**Dispersion**	**Pitch**
1	Constancy (zero dispersion)	Constant all parameters	6sec	10.5grains/sec	0 semitones	D6
2	Constancy (2-octave dispersion)	Constant all parameters	6sec	10.5grains/sec	2.4 octaves	random in range
3	Density	Increase	6sec	2.5→16 grains/sec	0 semitones	D6
4		Decrease	6sec	16→2.5 grains/sec	0 semitones	D6
5	Dispersion	Increase	6sec	10.5grains/sec	0 sem. → 2.4 oct.	random in range
6		Decrease	6sec	10.5grains/sec	2.4 oct. → 0 sem.	random in range
7	Pitch	Increase	6sec	10.5gr/sec	0 sem.	D6→E8
8		Decrease	6sec	10.5gr/sec	0 sem.	F#8→E6

2.3 Visual Stimuli

Eight videos were created as possible congruent visualizations of the sonic stimuli presented in the previous section, using recorded hand gestures. Each video lasted 6 seconds and was recorded using a Nikon D330 digital camera. The range of possible gestures was restricted to movements produced from the right hand's palm and fingers. In order to limit the endless variability of human movements, a forced- choice method of research was selected, narrowing participant choices to pre-recorded gesture representations.

The videos have been created so as to examine the main hypotheses explicated in the previous section. A secondary goal was to study gestures which can be recognized later by the hand gestural controller *Leap Motion*[2], so as to artistically exploit the results of the study at a later stage. Bearing in mind the limitations of the above technological device and, of course the type of movements we could associate with our auditory stimuli, we created gesture-videos characterized by four basic elements: i. lack of movement, ii. changes in kinetic energy and finger velocity (palm and finger movement), iii. changes in the surface of movement (palm opening/closing), iv. changes in the direction of movement along the y-axis. Each video is hypothesized to be congruent, with one of the sound conditions described in section 2.2, and incongruent with the other auditory stimuli (See Table 2).

[2] Leap Motion Inc. "Home". [Website] https://www.leapmotion.com/

Table 2. Visual Stimuli: Gesture's Description and Sound Mapping

Video	Gesture description	Congruent Sound
1	Palm and Fingers are open in the center of the screen - Motionless Gesture	Sound 1 – Constancy (zero dispersion)
2	Fingers moving continually with constant velocity - No changes in x or y axis	Sound 2 - Constancy (2-octave dispersion)
3 (See Fig. 1)	Palm and Fingers closed in the center of the screen - Gradual palm opening and increase of movement's surface - No changes in x or y axis	Sound 3 – Increasing Density
4	Palm and Fingers opened in the center of the screen - Gradual palm closing and decrease of movement's surface - No changes in x or y axis	Sound 4 – Decreasing Density
5	Palm and Fingers in the center of the screen - Initially still but gradually moving with increasing intensity - No changes in x or y axis	Sound 5 – Increasing Dispersion
6	Palm and Fingers in the center of the screen - Initially moving with decreasing velocity and finally reach immobility - No changes in x or y axis	Sound 6 – Decreasing Dispersion
7	Palm moving upwards on y axis	Sound 7 – Increasing Pitch
8	Palm moving downwards on y axis	Sound 8 – Decreasing Pitch

Fig. 1. Gesture no. 3 (Palm Opening) - frames at 0-3-6 seconds respectively

2.4 Procedure

The research was performed using a personal computer. The auditory stimuli were presented via headphones, in order to achieve optimal listening conditions and avoid distraction by external parameters. Initially, the participants had to listen to all eight sound tracks of the study. The aim was to get acquainted with "granular textures" and - perhaps - to observe the sounds and their different sonic characteristics per se (without involving the concept of movement). After this, the study was divided in three different parts.

The participants went through eight different pages/screens that contained the eight videos (visual stimuli) described in the previous paragraph. Each page, presented one of the eight different auditory stimuli (described earlier in paragraph 2.2) as a soundtrack to the videos; that is, all eight videos were presented in one page accompanied by the same sound track. The participants were asked to see and listen to all the videos. In the first part of the study, listeners had to select up to three gestures that they considered to be the best representation of the sound. In the second part, the participants had to choose the most representative sound from the three they had selected. In the third part, participants encountered a screen/page that contained the all sounds and all videos (without sound) and they had to make a one-to-one mapping between them, i.e., they had to match every sound with a unique gesture representation (video). The participants had to fulfill these three tasks in fixed order, aiming to examine how they would respond to conditions that were gradually becoming more restrictive. Our aim was to investigate if different visualizations could potentially represent the same sound stimuli (as outlined in the 1st task), as well as to establish direct correlations between the gestures represented on the videos and the sonic stimuli when the possible choices were progressively limited by the participants themselves (through the 2nd task) and also on a one-to-one association (3rd task).

3 Results

The data analysis is divided into five different sections based on the hypotheses presented above (section 1.3). In total, 64 different combinations of sounds and gesture representations have been investigated (eight sounds * eight gesture videos). In this report we present results for all 48 participants as a single group of listeners. Initial examination of responses shows that both musicians and non-musicians selected similar gesture representations for the auditory stimuli – this analysis (including minor differences between the sub-groups) will be reported in a future publication.

In order to facilitate the presentation of data analysis, we use abbreviations for the hand gesture videos and for the different parts of the research procedure (1st part - Multiple Choices, 2nd part - Only One Choice, 3rd part- Matching). As the results of the 1st and 2nd part (and even the 3rd part) of the experiment are very similar, and due to restrictions of paper length, in the discussion below we will present the results for the first part of the study (Multiple Choices) and refer to the other parts only when necessary.

Table 3. Code names for hand gestures

Code Name	Description	Code Name	Description
[P=]	Palm still	[F<]	Still to moving fingers
[F=]	Moving fingers	[F>]	Moving to still fingers
[P<]	Palm opening	[U]	Moving up
[P>]	Palm closing	[D]	Moving down

3.1 Constant sound

Choosing the most representative gesture for the sound which is a constantly repeating pitch at a constant grain density, seems to have prompted participants to a variety of different responses as seen in Figure 2a.

Specifically, at the first part where the participants could choose up to three possible answers, most of them associated this sound with the gesture [U] that shows the hand moving upwards on the vertical axis (25.97%); they associated also this sound with the gesture [P=] that shows a still gesture (23.37%) but also with the gesture [P<] where the hand palm is gradually opening (22.07%). Similar associations are given at the second part of the experiment. At the final part of the experiment, however, 87.5% of the participants associated the constant sound with the still gesture [P=].

The choice of the still gesture indicates that they tend to associate a sound that does not change during its duration with a hand movement that also does not change. On the contrary, the association with changing gestures [P<] and [U], maybe shows the tendency of listeners to represent the evolution of time that is the only changing parameter here. It is also noteworthy that gestures [F =], [F <], [F>] were selected in a small percentage (or not at all).

3.2 Changing Density

In Figure 2c, we observe a clear preference of the participants to correlate the increasing density sound with the gesture indicating palm opening [P <]. The next most prevalent answer is the [F <] video (increasing kinetic energy and speed of fingers). The response rates are as follows: at the first stage, the gesture [P<] involves 40.5% of the participants' answers and gesture [F<] involves 22.78%.

The participants associated the sound that is characterized by decreasing density mostly with the gesture closing palm gesture [P>]. More specifically, at the first stage, the gesture [P>] involves 36.66% of the participants' answers and gesture [F>] involves 22.22%.

3.3 Constant/ Changing Dispersion

When associating a sound with constant dispersion with a gesture representation, the majority of the participants chose to correlate this auditory stimuli with the video [F =] with response rates 58.82% at the first part of the experiment – see Figure 2b. The random scattering of grains within a certain range of frequencies was associated with the gesture that depicts the fingers of the hand moving constantly.

Participants' answers gave a fairly clear image concerning the association of a sound characterized by increasing dispersion with a gesture. Most of them chose gesture [F<] that shows the hand's kinetic energy and the fingers' speed increasing as the most representative (51.42%). But, also, 22.85% of the answers concerned the [F=] gesture that involves moving fingers at a constant rate. The association of sound characterized by decreasing dispersion, led the participants to select the video [F>] (40.27%) and we also observed a preference for gesture [F=] (26.83%).

3.4 Changing Pitch

The participants' answers when associating an increasing pitch sound with a gesture showed clear preference for the gestures [P<] and [U]. Specifically, at the first stage 43.15% chose the [P<] video and 34.73% the [U] video. At the final stage (one-to-one matching), 66.66% showed a clear preference for the gesture [U].

Finally, when associating a sound with decreasing pitch, the participants chose the opposite gesture representations. 26% chose the gesture [P>] and 31.95% the [D]. At the final part, most of the participants chose the [D] representation (60.41%).

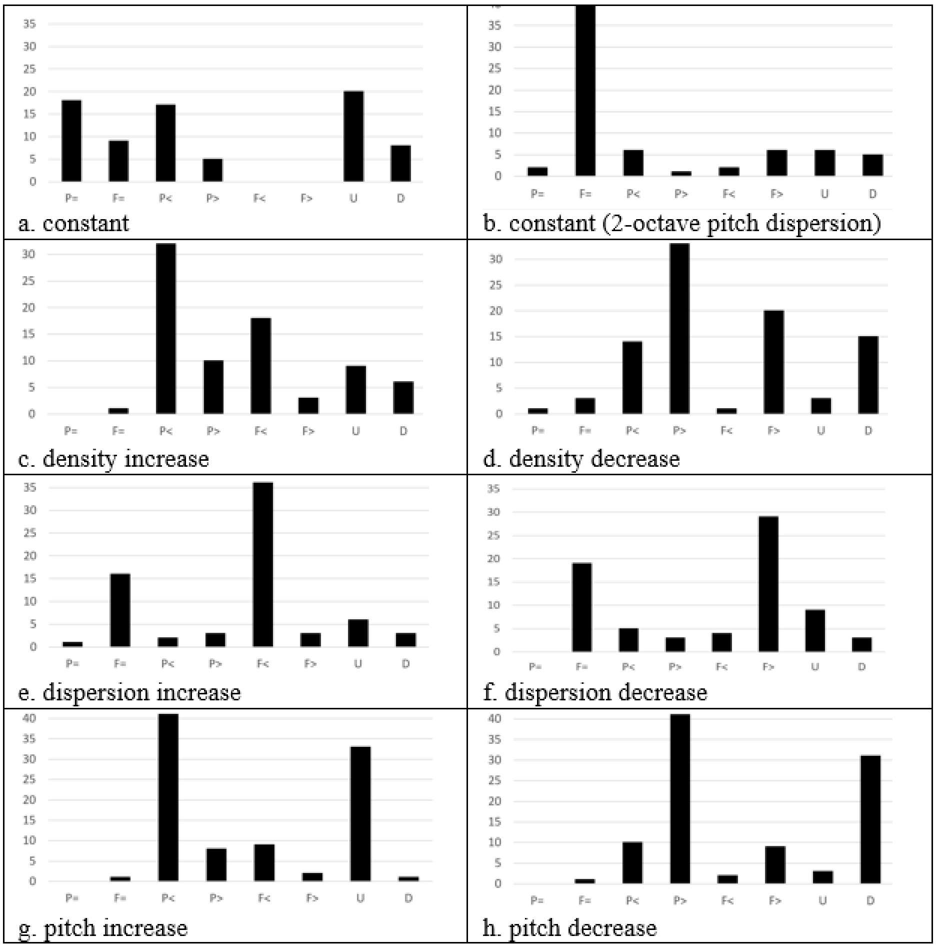

Fig. 2. - Bar diagrams showing number of times each of the eight gestures (P=, F=, P<, P>, F<, F>, U, D) have been associated with each of the eight sound stimuli during the 1st stage of the experiment.

3.5 Opposite Sound Pairs

The participants associated opposite pairs of auditory stimuli (characterized by increasing/ decreasing density, dispersion and pitch), with pairs of gestures exhibiting a reverse movement (increase and decrease of movement's surface/ kinetic energy and fingers' velocity/ upward and downward gesture on y-axis). In the majority of cases the number of responses was similar between the opposite correlations. In some cases, small asymmetries and pronounced tendencies for one of the two opposite states (ascending or descending) occurred. The following table illustrates these relations.

Table 4. Total amount of participant' responses concerning opposite sound pairs

	Associated Gesture	**1st stage - Multiple Answers**	
		Total	**Percentage %**
1st sound pair (density)	[P<]	32	40.5
	[P>]	33	36.66
	[F<]	18	22.78
	[F>]	20	22.22
2nd sound pair (dispersion)	[F<]	36	51.42
	[F>]	29	40.27
3rd sound pair (pitch)	[P<]	41	43.15
	[P>]	41	42.26
	[U]	33	34.73
	[D]	31	31.95

4 Discussion

The present study followed a forced- choice methodology. Participants were asked to associate musical stimuli with hand gestures and were not allowed to make their own gestures to visualize the sound stimuli. Should participants had produced gestures that embody sounds in a free-representational manner (see, for example [11], this would have resulted in obtaining a too large variety of gestures on pre-existing and well-established norms (e.g., pitch in relation to vertical height time in relation to horizontal axis). As such, this approach would not enable us to delve into more subtle, yet discernible approaches in gesture representation (e.g., movement of fingers). Participants had to associate auditory stimuli that consisted of diverse sound characteristics (1. constant/ changing density, 2. constant/ changing dispersion, 3. changing pitch) with gesture representations that also manifested manifold characteristics (1. lack of movement, 2. alternations in the surface of movement, 3. kinetic energy and fingers' velocity, 4. direction of movement). When we asked 48 participants to combine the concepts of sound and movement, and to discover how different changes that concern sounds made in the context of granular synthesis could be represented via hand gestures, many of our initial hypotheses have been confirmed. At the same time, new and interesting findings became apparent.

4.1 Constancy

Concerning the constant sound (track no. 1), the participants did not agree on the type of gesture that would represent this auditory stimulus. There was no strong correlation between this sound and what was hypothesized to be the congruent visual stimuli (i.e. static image), but, instead, various different gestures were associated with this sound. The association of the constant sound with the motionless gesture only partly confirms our initial hypothesis.

The association of constant sound with the two other options (the gradual opening of the hand palm [P <] and the upward movement on the y-axis [U]) underlines the participants' inclination to represent the evolution of time. Although people tend to represent time on the x- axis [10], the lack of this choice in the visual stimuli has prompted participants to other matches (opening palm and y-axis).

4.2 Density

The sound and gesture associations that concerned the auditory stimuli with changes in the grain density (tracks no. 3 and 4) showed common trends for listeners in all the parts of the study: participants preferred the opening palm gesture [P <] as more suitable for a sound that is characterized by increasing density and closing palm gesture [P>] for decreasing density. There is, therefore, a tendency to correlate the increase of the sound grain with the increase in the surface area of the movement and vice versa.

4.3 Dispersion

Regarding the sound characterized by constant dispersion (track no.2), the results show, as hypothesized, that it was mostly associated by participants in all three parts of the study, with the gesture [F =]. That is, listeners correlated this sound with a gesture that is characterized by a continuous motion of the fingers at constant velocity.

The participants’ choices concerning the sounds characterized by changing dispersion (tracks no. 5 and 6), showed a clear preference for associating these with the gestures characterized by a change in kinetic energy. The sound with a gradual increase in dispersion was associated with gesture [F <] (gradually increasing kinetic energy of fingers), and, vice versa. The next option was gesture [F =] that involves constant moving of fingers. In any case, it seems that listeners tend to represent changes in sound dispersion with intense kinetic activity of the fingers (static/increasing/decreasing).

4.4 Pitch

Changes in pitch were associated with changes of movement on the vertical axis, as hypothesized, but also with modifications to the surface of movement. Participants’ answers showed that they tend to associate changes in pitch with changes in the direction of movement on the vertical axis. Thus, a sound characterized by increasing pitch was represented by a gesture showing the hand ascending on the y-axis, while a sound of decreasing pitch was represented by a gesture where the hand descends along the same (vertical) axis. This finding (correlation of pitch to the vertical axis) has been explored and confirmed by the majority of researchers in the last fifty years [6], [9].

Additionally, a high number of the participants associated the increase in pitch with a gesture of an opening palm (increase of the surface of movement) and vice versa (for a sound characterized by pitch decrease). This conclusion matches Antovic’s findings concerning the correlation between pitch and size concept [13]. The latter observed that when people describe sounds with metaphors, there is a tendency to translate high pitch sounds into large-scale shapes, while sounds of low pitch were associated with small-scale shapes.

4.5 Opposite Sound Pairs

Finally, the results showed that the predicted association of opposite sound couples with opposite gestures has been confirmed. Listeners showed a tendency to match opposite auditory stimuli pairs with opposite gesture couples.

Pairs of sounds characterized by increase and decrease in density, dispersion, and pitch were identified by the participants and have been associated with gestures exhibiting contrasting intensity and direction (increase and decrease of movement's surface/ kinetic energy and fingers' velocity/ upward and downward gesture on y-axis). This finding is in line with previous studies exploring the existence of proportions when associating opposite auditory pairs and gestures, such as the research carried out in 2006 by Eitan and Granot [6].

5 Conclusion and Future Directions

In the present study, we investigated gestural representations of different sound parameters of granular synthesis, including density, dispersion and pitch. Constant and changing conditions of the parameters mentioned above were selected, and we examined if they were associated with specific hand movements. The principal scope of this study has been to assess how familiar sensorimotor experiences correspond to sonic stimuli in a forced-choice design, using Granulab as a tool for developing the sonic stimuli. Though studies have been conducted on artificial/tangible musical instruments as compositional tools using granular synthesis mappings [14], in this case our aim was to focus primarily on putting pre-existing associations between gesture and sonic events to the test, and not the compositional approach in itself. By offering a three task approach to the participants (primary selection of up to three gestural representations to each stimulus; narrowing this selection to one gesture per stimulus; free association of gestures to stimuli) our aim to assess the association between a specific set of gestures to sounding responses has been achieved.

The results confirmed most of our hypotheses and correspond to the findings of previous studies. At the same time, new interesting outcomes emerged and enriched our knowledge about sound and motion correlations. Absence of sonic manipulations (constant sound) has been primarily associated, as hypothesized, with lack of movement; we observed, however, an increase in overall hand surface and an upward movement on the y-axis which we conjecture corresponds to the 'temporal movement' of a sound event. Changes in sonic density have been associated mostly with changes in the movement's surface, while changes in dispersion have been associated with changes in the kinetic energy and finger velocity. The concept of pitch was closely correlated with the direction along the vertical axis (as expected) but also with the surface of movement (palm opening and closing). Finally, the participants tended to correlate opposite pairs of auditory stimuli with opposite gesture couples.

Future research may examine different sound synthesis parameters and well as movement gestures in different combinations, and may move beyond the forced-choice methodology used in this study to use gestural controller and/or motion capture techniques to track freely shaped gestures by participants exposed to different sound stimuli.

In conclusion, an artistic and research blend as a future scope of research would be a great challenge and a logical continuation of the current study. Using a gestural controller (e.g. Leap Motion Controller) and appropriate software (e.g. Pure Data or Max/MSP) could easily transform the study's results and the sound-gesture mappings into an interesting artistic interactive music project.

6 References

[1] M. Leman, "Musical gestures and embodied cognition," *Actes des Journées d'Informatique Musicale (JIM)*, Mons, Belgium, pp. 5–7, 2012.

[2] A. R. Jensenius, M. M. Wanderley, R. I. Godøy, and M. Leman, "Musical Gestures: Concepts and Methods in Research," in *Musical Gestures: Sound, Movement, and Meaning*, New York: Routledge, 2010, pp. 12–35.

[3] M. Leman, *Embodied music cognition and mediation technology*. Cambridge: MIT Press, 2008.

[4] R. I. Godøy and M. Leman, "Why Study Musical Gestures?," in *Musical Gestures: Sound, Movement, and Meaning*, New York: Routledge, 2010, pp. 3–11.

[5] A. R. Jensenius and H. T. Zeiner- Henriksen, *Music Moves: Why does music make you move?* Massive Open Online Course [MOOC]. University of Oslo, 2017.

[6] Z. Eitan and R. Y. Granot, "How Music Moves: Musical Parameters and Listeners' Images of Motion," *Music Percept.*, vol. 23, no. 3, pp. 221–247, 2006.

[7] A. Gritten and E. King, Eds., *New perspectives on music and gesture*. Aldershot, United Kingdom: Ashgate, 2011.

[8] V. Iyer, "Embodied Mind, Situated Cognition, and Expressive Microtiming in African-American Music," *Music Percept.*, vol. 19, no. 3, pp. 387–414, 2002.

[9] M. B. Küssner and D. Leech-Wilkinson, "Investigating the influence of musical training on cross-modal correspondences and sensorimotor skills in a real-time drawing paradigm," *Psychol. Music*, vol. 42, no. 3, pp. 448–469, 2014.

[10] D. Casasanto and K. Jasmin, "The hands of time: Temporal gesture in English speakers," *Cogn. Linguist.*, vol. 23, no. 4, pp. 643–674, 2012.

[11] M. B. Küssner, "Shape, Drawing and Gesture: Cross- Modal Mappings of Sound and Music," King's College London, 2014.

[12] T. Lotis and T. Diamantopoulos, *Music Informatics and Computer Music.* Athens: Hellenic Academic Libraries, 2015 (In Greek)

[13] M. Antovic, "Musical Metaphors in Serbian and Romani Children – an Empirical Study," *Metaphor Symb.*, vol. 24, no. 3, pp. 184–202, 2009.

[14] G. Essl and S. O'Modhrain, "An enactive approach to the design of new tangible musical instruments," *Organised Sound*, vol. 11, no. 3, pp. 285–296, 2006.