Ms. Cora Gasparotti - ITALY

Biography

Italian performer and choreographer, Cora Gasparotti, stands among the most active exponents of new technologies for performing arts and dance. Member of the Casa Paganini InfoMus research and development team and CID-UNESCO, her research pushes her to explore new technologies, such as motion capture, metaverse and virtual reality, in search of a new digital humanity. Her screendance works travel all over the world qualifying among the winners of numerous international competitions. In 2020, her "Crisalide" is the first screendance short released on Amazon Prime Video.

After earning a Bachelor's Degree in Technique and Analysis of Contemporary Dance, in 2022 she obtained with the highest marks the Master's Degree in Teaching of Choreutic Disciplines at Accademia Nazionale di Danza in Rome.

As dancer she is part of productions of choreographers such as Enzo Cosimi, Marco Donnarumma, Stian Danielsen, Giovanna Velardi, Alberto del Saz, Ludovic Party and Mario Piazza.

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« Sonified Proprioception Technique – S.P.T. »

An in-depth study of the possibilities of sonification for the teaching of contemporary dance.

Abstract

This presentation aims to document briefly the research path that led to the design of Sonified Proprioception Technique - S.P.T., from the basics to the outlining of possible future developments of the system, which is an educational approach of dance assisted by techniques of movement analysis and sonification. The complete research paper covers different topics that collaborate with the nature of the multidisciplinary project, deepening areas such as sound, dance history, technology, methodology, research and neuroscience, in order to underline the foundations of the system and justify its development and final intentions. The presentation designed for the 58th Congress of Dance Research held by CID Unesco will be focused on relationship between sound and movement, the reasons that pushed the search itself, the link between sonification and proprioception and some representative case studies and results.

The results obtained and the rich and promising scientific and artistic documentation behind them show how sound can be an effective proprioceptive instrument for teaching and learning, opening up the possibilities of introduction within the study of dance in a functional and incisive way.

1. Manifestations of the music-dance relationship in history.

The union between music and dance has its origins in the dawn of time, in the Greek theater, but with good probability even previously it was a practice not infrequently. If we try to imagine a prehistoric rite, most of us visualize drums and bodies that move rhythmically around a fire, and not far away in time was the spectacular event corresponding to the Greek tragedy. In fact, this was not built as a purely literary art form, but rather involved the intervention of various scenic elements such as music, singing, choreography. Today it is perhaps complex to understand this type of representation, which is why it is complex to penetrate its essence even in areas that study its origins, meanings and dynamics, but it can be approached by imagining the "more recent" Renaissance Melodrama, which was born not by chance precisely from a desire for recovery of the Greek tragic genre.

In Greek tragedy that *mousikè* is fully realized , which for the ancient Greeks was not identified with music alone or poetry, but was constituted by the perfect fusion of the expressive codes of poetry and song, to which dance or choreography is added, and which for the young Greeks it constituted one of the foundations of a good education in art, and consequently, in civilization. The relationship between dance and music continues in history between ups and downs, also due to the insertion of dogmas imposed by religion, which demonized dance as impure and rejected a whole branch of music, especially that dedicated to choral and festive events. . Over time their relationship is restored thanks to the dance suites and the first attempts at notation of the dances, which for the most part provided a strong analogy with the notes on the staff or the rhythm. Well known are the tables of *Orchésographie* by *Thoinot Arbeau* of 1588 or the *Feuillet-Beauchamp method* of 1700. Music and its structures were used more and more to help the teaching and study of dance and returned to be part of the good education within courts and noble families, while outside the palaces the festive events and the spontaneous manifestations of popular dance began to take hold again, getting closer and closer to that mixture of hybrid traditions between aristocratic and folkloristic that over time will lead to the definition of academic dance and its steps.

In the following centuries, music took several paths, dividing itself between music composed for listening and music composed for dance, which is why in the development of ballet and academic dance the association with music is strengthened as much as possible. In the course of history, however, there is no lack of choreographic productions on concert music, which

allowed the choreographers to concentrate on the vocabulary of the movement as an end in itself, free from the plots, characters and impositions of the libretto.

It is in the twentieth century that most of the experiments in this regard take place. In the world of dance and the study of movement in general, as early as the end of the 19th century, music began to be considered in different ways, considering different traits on the basis of its purposes, some only the rhythm, some its ability to evoke images, some its easy symbiosis with dance and gesture, who the possibility for it to live with dance without necessarily following it and vice versa, until it comes to speaking, more than about music, of sound and its multiple qualities.

The relationship between music and dance begins to become of educational interest, not only for dancers, through the experiments of Euritmica by Dalcroze in Hellerau and the Music Visualization commonly taught at Denishawn in California, until it leads to the performance sector with pioneers such as Doris Humphrey and Isadora Duncan and experimenters such as Merce Cunningham.

As mentioned above, the methods of investigation of this pair took different paths, at the forefront were the precision studies on the rhythm of Dalcroze, who saw in the physical and precise representation of the rhythm an effective method of music education. It is said that it was precisely these studies that inspired all subsequent modern dance, although this moved away from the rigid and constrained representation of the musical phrase, preferring a wider interpretation of the phrasing and with greater degrees of freedom. In this regard, it is impossible not to mention Isadora Duncan who danced to known and loved music in concert halls, giving the movement the value of a physical translation of the music and its suggestions.

It is no coincidence that not infrequently speaking of modern dance and its pioneers we speak of interpretative dance, which seeks information and ideas on the mood, history and dramaturgy in the music itself. Duncan herself mentions music as the core of her work, praising Wagner and placing it as the founding principle of teaching in her school:

> *"He was the first to conceive of dance as born of music. This is also my conception of dance, and for it I strive in the work of my school. "*

Of a similar conception is the Music Visualization imparted in the Denishawn school about the same period, a technique that will greatly influence the artistic and didactic work of the famous Doris Humphrey, who was unable to study directly with Dalcroze but was a pupil of his students such as Lucy Duncan Hall and Andreas Pavley in Chicago and Marion Kappes at Denishawn school in California. The latter was a very prominent center for this type of study. Founded by

Ruth St. Denis and Ted Shawn, the institute welcomed Humphrey first as a student and then as a dancer of the company accompanying her towards her career as a choreographer also thanks to the appreciation obtained by the musician Louis Horst.

The musical visualizations of the Denishawn group were a departure from the previous use of the dance world: they were works that stripped of ornate costumes, pseudo-ethnic exoticism and narrative plot designs. Attention gradually shifted to the choreography, designed to synchronize the audience's visual and sound experiences.

Denishawn's musical visualizations were abstract. Dancers no longer needed to portray princesses, sylphs or fairies - they could just dance and bring their own personality pure and simple to the stage.

Despite her separation from the company in 1928, Humphrey continued to create musical visualizations. Others began to embrace the genre as well, but the concept slowly fell into disuse after 1930, not only because of public opinion, but also because of the first negative feedback from critics. At the forefront, critic John Martin wrote in 1936:

> *“Through a complete misunderstanding of Isadora, music became the primary and indispensable medium of dance about thirty years ago, and that strange anomaly known as interpretive dance has spread around the world.*
>
> *American dance's attitude to music is by far its weakest point. Nobody, anywhere in the world is more justified in dabbling in musical interpretations dancing under the illusion of being modern. Music is entirely secondary to any self-respecting dance form; it is an accompaniment, a background [...]. "*

Author Stephanie Jordan takes stock in her book *Moving Music*, noting that even choreographers heavily influenced by Jaques-Dalcroze's work, such as Nijinska , Lopukhov and even Humphrey later claimed their distance from it.

Jordan explains:

> *“The equivalence between the arts became irrelevant. [...]*
>
> *While music was once considered a liberating mechanism, it was gradually viewed with suspicion: it could limit the development of choreography. We sought autonomy for dance, alongside new structural relationships between sound and movement. "*

The more the popularity of modern dance grew, the more it was possible to commission newly created musical works on dance, rather than dancing already existing and famous pieces. The choreographers began to follow and develop their interests in the concepts of space, time and energy, in order to found new shores for a renewed vocabulary of movement and choreographic forms free from musical domination.

For many, the divorce of music from dance may have found its apex in the artistic partnership between choreographer Merce Cunningham and composer John Cage around 1950. Upon in-depth analysis, it is clear that this may only be partially true, as some works by themselves managed through the creative division between dance and music to consider their coexistence interesting in some respects, albeit according to other principles and modalities. In respect of the creative freedom of both arts and of that respect boasted by Martin, the two polarities enjoyed equal importance, as did the visual arts sector often responsible for the scenographic apparatus, moving away from the considered banal "*mickey mousing*", or rather the didactic representation of musical phrasing, but approaching new relationships and correspondences fueled by chance.

To corroborate this vision is one of the perhaps lesser known but more experimental works of the choreographer, *Variation V.*

Presented for the first time at the Lincoln Center in New York in 1965, *Variation V* is an experimentation of the relationship between dance and sound. Cunningham, under the proposal of composer Cage, employs dancers as musicians through a finely designed system of sensors, by Billy Klüver, which allowed dance to be the generative variable for a wide range of factors. As they danced, the bodies of the dancers influenced the fields of some antennas placed on the stage, which, sensitive to movement, sent electronic signals to the musicians. These, placed behind panels, manipulated the sound according to this information, determining its duration and repetition.

The type of instrument used came from an existing instrument called *Theremin*, an electronic musical instrument that does not require physical contact of the performer, invented in 1919 by physicist Lev Sergeevic Termen, known in the West as Léon Theremin (hence the name of the device). The *Theremin*, consisting of two antennas placed above and to the side of a container in which all the electronics are housed, is based on oscillators that produce, by altering their characteristics as a result of the presence of the musician's hands in the wave field, sounds.

Returning to *Variation V*, it is interesting to specify that, in a completely analogous way to sound, the light was also controlled by the data produced by the choreography, varying in intensity depending on its transit in conjunction with photocells. The visual part, on the other hand, was based on the methods of the case, as usual in Cunningham's works, and was created by Nam June Paik and Stan VanDerBeek. It consisted of a video in which the movements of the dancers on stage were intertwined with images taken from television shows and films.

It is Merce Cunningham who marks the advent of a dance seen as a flow of data capable of being reworked for multiple purposes, from visual art to sound, as evidenced by several of his experiments in fields still unexplored for the artistic world at the time and in particular of choreography, such as the famous software *Life Forms*, the live show *Biped* or its motor testament, *Loops,* an *open source* data base collected from *motion capture* by Cunningham himself, left to posterity with the free possibility of reworking them and transforming them into any type of work.

A few years after the beginning of these experiments, many others have contributed to the spread of this new vision of dance, movement and musical work in general. To name a few significant ones for the state of the art, we can refer to the multimedia systems based on the *EyesWeb platform* developed for the musical theater work "Cronaca del Luogo" by Luciano Berio on the occasion of the opening of the Salzburg Festival in 1999 from Centro Casa Paganini - InfoMus of Genoa in collaboration with the staff of the Centro Tempo Reale, in which the protagonist character through sensors inserted in the costume and a system of cameras attentive to his movement in space could manage a sort of *morphing* between the personalities of the character by changing in real time his voice from one character to another; or you can refer to the numerous series of meetings and performative projects by the InfoMus Laboratory of Genoa and in collaboration with international artists such as Virgilio Sieni, Muriel Romero and the French company K.Danse directed by choreographer Jean-Marc Matos on the occasion of the DANCE project (2015-2017 - EU Horizons 2020), the which had as its objective to investigate how the emotional and relational qualities body movement can be expressed, represented and analyzed by the auditory canal.

The legacy left by Merce Cunningham and the works cited to today's dance is immense. In fact, it is not difficult today to have evidence of choreographic works that rely on technology, exploiting data born from dance for different purposes, from performance to research, not only in the artistic field. If in the performative field, Alexander Whitley's company is slowly establishing itself as one of the major centers of hybrid production between movement and

technology, especially as regards *rendering* 3D, also coming to robotics experiments and *worldwide live renderings*, in the research field it is necessary to mention projects such as Wholo Dance Project, a system for archiving and teaching dance with more than revolutionary features, which will be further explored in the course of the chapters subsequent.

Departing for a moment from the history of dance, we can say that the first known example of an interactive music / dance system is Erkki DIMI-O (1971) by Kurenniemi , one of the pioneers of the music sequencer. The system made it possible to play a pre -composed musical score through the control of movement, obtained with still rudimentary computerized vision systems. Unfortunately, Kurenniemi's visionary invention did not receive much attention outside the DMI (Digital Music Instruments) community so it was not further developed after the initial prototype.

The same cannot be said for the Very Nervous System by David Rokeby, which undoubtedly represents a real milestone in dance technology, widely celebrated in 1986 at the Venice Biennale. The work was shown primarily as an interactive installation in galleries and public spaces but the software was used in subsequent years in several dance performances from Todd Winkler's *Dark around the edges* (1997) to Ventura Dance Company's *Heliopolis (2014).*

Finally, it is important to point out that there is, about interactive systems for sound and movement on various levels of interest, also a large literature that winds through articles, conferences and annual international conferences including NIME (New Interfaces for Musical Expression) and MOCO (Movement and Computing), in which scientists and artists of various kinds have the opportunity to discuss discoveries, interests and future developments of the aforementioned themes.

2. Scientific foundations: Interactive Sonification

Sonification is defined as:

> *"The transformation of data into sound perceptions or the generation of sounds dependent on data as long as it is systematic, objective and reproducible."*

In the first chapter of the text (pg . 1-2, T. Hermann, A. Hunt and JG Neuhoff , 2011) we read:

> *“As with all interdisciplinary research efforts, there are significant obstacles to interdisciplinary research on Auditory Display and sonification . The difficulties range*

from the difference in theoretical orientations between disciplines, to the words used to describe the work. Interdisciplinary dialogue is crucial for the advancement of the Auditory Display and Sonification . However, the field faces the challenge of developing and using a common language in order to integrate many different "disciplinary" ways of speaking, thinking and dealing with problems. On the other hand, this obstacle often offers great potential for discovery because these divergent ways of thinking and speaking can trigger creative potential and new ideas. "

Sonification is in fact a field that finds its strength in multidisciplinarity but also at times its weakness, having difficulty in defining an effective common language or classification. Auditory displays, which as we have anticipated exploit sonification, are already widely used, even trivially in accompanying and corroborating the images we see on the display of household appliances or our mobile phone. Just think of the sound we hear when we insert a USB key into the port of our computer: it is different between input and output and allows us to know that the system has detected the presence of the device even without reading the pop-up window that appears near the bar of the desktop. The auditory displays exploit the characteristics of the auditory system to recognize changes and temporal patterns which are useful for example in the recognition of complex events, which involve changes in time, alerts that require an immediate response and in all cases where it is not possible or not convenient to use a visual display. Furthermore, sonification takes advantage of the higher temporal resolution of the auditory system compared to the visual system.

3. Experiments that use sonification for proprioceptive and learning purposes

In this paragraph, studies that confirm the efficacy of sonification as a proprioception mechanism are investigated.

First we find confirmation in the experiments of EnTimeMent , FET ProActive research project. During some EnTimeMent workshops, sonification was the protagonist of experiments and demonstrations, for example through the sonification of correct posture or the execution of a motor task. In particular in the research activities conducted by UCL-University College London in EnTimeMent, on the analysis, prevention and treatment of chronic pain, sonification is designed to provide biofeedback on simple actions, such as getting up and sitting down, or in typical movements in simple movements in housework (such as housework), which may be

performed incorrectly due to chronic pain and the individual's compensations. The result of these however, offsets often aggravate the pain. A sonification system allows to produce a biofeedback in order to interact in real time with the user in order to induce him towards correct movements without the need for a physiotherapist to guide him from the outside or to look at himself in a mirror. In EnTimeMent and at Casa Paganini in general, research and development activities on sonification have been ongoing for many years and are based on a trans-disciplinary approach that involves the arts. In the article (A. Camurri, C. Canepa, N. Ferrari, M. Mancini, R. Niewiadomski , S. Piana, G. Volpe, J. Matos, P. Palacio, M. Romero, 2016) "*A system to support the learning of movement qualities in dance: a case study on dynamic symmetry*", a model is described, and one of its own implementation created with EyesWeb, which is based on the analysis of symmetry in full-body movement. The auditory feedback produced is designed to provide a reward system for the student who, wearing the accelerometers, tries to reproduce symmetrically the movement previously performed by the teacher. According to the authors, the sonification system conveys information about the level of coordination, symmetry and synchronization achieved by the student through the movement of the arms and consequently improves the learning of a certain quality of movement rather than encouraging the imitation of the teacher from the point of view of the exact trajectory of the movement. In 2019, in the same center, research continues on the use of sound to learn movement quality execution. In particular in the publication "*Does embodied training improve the recognition of mid-level expressive movement qualities sonification?"* , with the help of the choreographer Virgilio Sieni , the sonification of two mid-level features is deepened: fragility and lightness. Inertial sensors are placed on the dancer's ankles and wrists, and the study shows how the participants, some dancers, other amateurs, were able to distinguish the two qualities through the sound feedback obtained.

The studies that use sonification for the perception of movement are varied, and many are accompanied by dance, not surprisingly according to some studies (Bevilacqua et al., 2016) *"a methodological convergence in the creation of interactive systems between dance and music would be of help to both sectors for the structure of efficient motion-based sonification systems"*. Most of these studies aim to increase the ability of perception and awareness of movement, which is why they are often categorized as *"somatic sonification"*. To give some examples, this category includes, in addition to studies already described, the studies by Menicacci and Quinz (Menicacci - Quinz , 2006), in which sonification is used to control the posture of a dancer, the research of Jensenius and Berkstrand (Jensenius - Berkstrand , 2011) in which the possibility of the sonification of making involuntary micro movements of the subject perceptible, or the

writings of Grosshauser (Grosshauser et al. 2012) in which the jumps of a classical dance lesson are rendered sound, demonstrating how they can help the learning of that type of movements for students of various ages and levels.

The sonification of movement, however, is not limited to research relating to dance and its learning, but extends to medical areas in which proprioception is fundamental but encounters difficulties due to pathologies or disabilities.

In particular, two studies are cited that are particularly relevant. The first, held at the Leibniz University of Hannover, Germany, in 2018 (Ghai et al. 2018), uses sonification to allow the patient, through training sessions, to regain awareness of knee alignment. In detail, recordings were made in which patients repositioned the joint at different angles, with and without sonification, and then repeated after 15 minutes and after 24 hours. From the data collected, an increase in knee proprioception appears evident thanks to the sound feedback, remaining stable even in the recordings made after 15 minutes and 24 hours without sonification .

The second study, conducted in Marseille by Jeremy Danna and Jean-Luc Velay (Danna J. and Velay JL., 2017), exploits the sound feedback to compensate for the disturbance of proprioception of two subjects while learning to write new characters. In this case the sonification does not act as a confirmation of the proprioceptive system but replaces it where necessary, acting as a prosthesis and making audible parameters of the movement that otherwise the subject would not be able to perceive in any way. The exercise was performed by people with proprioception disorders and healthy subjects. The results revealed that the characters learned with sonification they were reproduced faster and more fluently than those learned without from both groups, with a greater difference for those with proprioception disorders; that subjects with proprioception disorders were able to learn them only if trained with sonification; that the performance of the subjects with proprioception disturbance returned to the pre - test level 2 hours after training with sounds.

Studies involving sonification in relation to movement also fall within the performative panorama and not only didactic and scientific.

An interesting example is the work of two artists, who have made artificial intelligence and sonification systems the center of their creations, Marco Donnarumma and Margherita Pevere. In *Eingeweide* (2018) created in collaboration with the Neurorobotics Research Laboratory, Beuth Hochschule Berlin there is a drastic form of body experimentation at the crossroads of body art, Tanztheater, sound design and media art. On the stage two bodies interact with each

other embodying corporeality and non-human postures while an autonomous prosthetic limb mounted on the head of one of the two performers mediates their interaction. An artificial intelligence system acts as a third interpreter controlling the movements of the robotic arm and generating the soundscape of the piece. The control signals are produced by the direct auditing of the muscle activity of the performers detected by a pair of Mechanomyograms (GPs). This system makes the performer and the algorithm dependent on each other, making the mutual learning process audible and revealing a visceral relationship between man and machine.

Another interesting example of research in the performative field is *Two Pandoras* by Muriel Romero and Jean-Marc Matos (2018-2019) in which sonification techniques are used to investigate how the kinesthetic awareness of the dancers' body can be enriched through the use of interactive motion analysis systems. The piece was born from the collaboration between K - Danse, the Stocos Institute and the Infomus Lab research team of the University of Genoa. In *Two Pandoras*, the relationship between the two dancers (Muriel Romero and Marianne Masson) arises from improvisation with sound and light entities that are generated in real time following their behavior through pressure-sensitive shoes, inertial sensors positioned on the joints and interactive lasers. placed on the wrists. The sonification in real time, possible through the analysis of algorithms created with EyesWeb, is made up of generative sound synthesis algorithms designed by Pablo Palacio. Motion analysis and sonification techniques were originally developed as methods for studying movement and enhancing sensory learning. This methodological convergence between scientific aims and artistic approaches suggests new possible insights for the development of research-creation frameworks.

It is no coincidence that the collaboration just described develops within the framework of the European *Wholodance project* (H2020 program) which places this combination at the center of its development.

Wholodance aims to develop and apply revolutionary technologies to dance learning in order to achieve results that will have a significant impact on different areas of the same. The project focuses on five main objectives: **Investigating body knowledge**, applying computational models to the analysis of emotional contents and creating techniques for the automated analysis of non-verbal expressive movements helping to deepen the principles of movement, learning, vocabulary and simulations related to dance practices; **Preserve cultural heritage by** creating a library of dance movements, recorded via *motion capture*; **Innovating dance teaching** , developing a life-size volumetric display that will allow students to literally enter the dance master's body; **Revolutionize choreography by** building an interactive repository of *motion*

capture libraries where the choreographers will be able to merge and assemble an infinite number of dance compositions; **Expand the accessibility to dance practice**, providing the possibility of using the database created through consumer quality motion capture devices such as *MS Kinect*, *Intel Real Sense* and others.

4. Sound - movement synesthesia

Synaesthesias play a very important role in matching sounds to movements in a coherent and effective way.

Synesthesia is a phenomenon in which a perceived element automatically evokes the sensation of another element that is not there (Cytowic and Eagleman , 2009) . Famous are the examples of musicians, composers such as the Finnish Jean Sibelius (Ekman , 1938) who, when he looked at an object colored green, felt in his head an F major chord or the physicist Feynman (1988) who in his autobiography says that every time he saw the equations he saw them a colors. The conditions described are today called grapheme-color and music-color synaesthesia, respectively. About twenty studies in recent years have brought evidence of the validity and reliability of these phenomenological reports in terms of their effects on both behavior and neural processes (eg Beeli et al., 2005; Laeng et al., 2011), so much so as to go further in the research and in-depth study of other associations. Although synaesthesia are often considered subjective phenomena, there are many associations that seem to have some instinctive aspect inherent in the majority of the population.

One of these is the movement-sound synesthesia, in which there is an activation of the rhythmic and auditory perceptions even when the subject is exposed to visual stimuli without sound. According to the phenomenological reports, each time these subjects were exposed to the vision of a visual object in motion, even without sound, their visual perception was accompanied by characteristic sounds corresponding to the movement in terms of speed of change, height, periodicity. Studies confirm these illusory auditory perceptions through experiments on synaesthetes and non-synaesthetes. One of these (Saenz and Koch, 2008) compares the skills of two groups, one of synaesthetes and one of non- synaesthetes , in a short-term memory task. Specifically, the results of 2 synaesthetes and 8 control subjects were compared, who were presented with rapid rhythmic sequences, similar to Morse code, composed of acoustic signals or visual flashes, asking them to evaluate whether two successive sequences (both auditory or both visual) were the same or different.

All subjects performed well in the auditory tests, but only the synaesthetes performed well in the visual tests. These results are consistent with the ability of synaesthetes to hear rhythms in visual tests. The responses to visualization of moving and fixed visual points were then measured. Synaesthetes reported sound perceptions only for the moving stimulus . Interesting responses to visual movement were also highlighted in synaesthetes compared to controls, on the bilateral superior temporal sulcus, an audiovisual integration site already reported in other studies. What is most interesting, especially in the use of these studies for the creation of interactive systems, is that the same region was highly reactive to visual stimuli in both synaesthetes and control subjects when subjected to a task that encourages related sound images temporally and that the same region responded to purely auditory stimuli both in the synaesthetes and in the controls, verifying its identity as a region of audiovisual convergence. From this it can be understood that synaesthetes have only a more reactive form of multisensory integration, which however occurs within the perceptual mechanisms of a large part of the population, making this type of synaesthesia more "objective" than others. It is no coincidence that most people tend to associate a very heavy or downward movement with a lower frequency sound and vice versa.

5. *Sonified Proprioception Technique* - SPT - Objectives, functioning, possible developments

The fundamental objective of the project is to allow the dancer and the teacher to be able to exploit the proprioceptive effect of sonification in order not to have to refer to the mirror for the correction of movement qualities, creating a constant immersive and interactive environment through sound. The latter, being consistent with the cross-modal characteristics of the perceptual system (Spence 2011) of the same student, acts as an amplification of the proprioceptive abilities through the auditory canal , creating an innovative biofeedback system in which the expressive motor components of the subject are sonified, in order to support didactic, creative and performative activities.

The possibility of being able to "listen to your own movement" allows you to create a methodology that integrates listening, understood as an active, introspective and conscious state of the body, and auditory listening, in order to reduce distractions and give an almost tangible form to the intention of the movement itself.

Speaking of intention, in fact, is not a risky imaginary, but rather a new possibility of the motion capture and analysis systems that the EnTimeMent project is working on . This means that, with

time and the growth of the project, it can be hoped not to limit oneself to the sonification of quality of movement such as weight or lightness, present in the simulation that will be described later, but rather to explore the intentions of the movement and the its resulting qualities, allowing the dancer, the teacher, the choreographer to go to work and correct even more detailed details, responsible for the emotional aspect and the communication of the *piece* .

In this case, the system would be at the service of various areas and objectives:

- Methodological Technical Teaching
- Support for improvisation and the study of movement qualities
- Analysis of the synchrony and qualitative / emotional coherence of a group
- Qualitative / emotional analysis of an individual
- Broadening of the consciousness of the body rhythm and of one's own motor signature
- Search for the profound truth of the movement and its reasons, minimizing "imitation" of emotions
- Increased sensitivity to listening by the performers
- Support to dance and movement, even in social situations, for people with visual impairments

It is evident that, as already happens in some projects, also previously described, this system can adapt to objectives other than the dance lesson, both by addressing artistic aspects of a more **performative and interdisciplinary taste**, and by making contributions to fields such **as rehabilitation**, **education and didactic simulations**, teaching **sports disciplines**, **monitoring situations in public environments** or, following the Labanian path, support **for industrial work**, in particular for **human-machine interaction** .

However, let's go into the details of the hypothetical functioning of the system in the case of Methodology of Dance.

Thanks to the ongoing development of less invasive possible *mocap systems* and wearable sensors, it is assumed that the dancer can move freely in the room by performing the necessary movements, without being limited in his motor possibilities.

Let's analyze the steps:

1. The dancer moves around the room performing the required exercises or movements

2. The movement of the dancer is recorded and captured by a *motion capture system or sensors*, accurate enough not to alter the collected data but from have an analysis as clean as possible and therefore coherent for the purposes of sonification
3. The collected data are transformed into sound by the system which, through predefined wide range ranges, recognizes aspects of the movement such as particular **qualities**, for example fragility or fluidity, or **parameters**, such as weight, speed, space, depending on the settings of the session.
4. The sound is made audible in the way most suited to the session (earphones, speakers, etc ...) to the dancer or dancers.
5. The dancer listens to the sound and is conditioned by the pre-established sound objective, seeking the truth of the movement in the body and not in a visual form.

The system wants to be as customizable as possible during its years of development, allowing over time to choose which parameters to sonify , according to which time scale the movement should be analyzed and for which type of activity and method of use the session is being started, in in order to allow a functional and optimized experience.

Specifically, this first simulation, designed for an educational context, intends to sonify the salient moments in which the weight reaches its maximum degree of gravity or suspension, using the verified model of the *mid-level feature* "Lightness" (Niewiadomski , Mancini , Cera, Piana, Canepa, Camurri, 2018) and the control variable "relevance", in order not to obtain an excessively saturated and therefore ineffective sonification.

The hope is that a technique can be combined with this system, which can base its lessons on an integrated study of movement through sonification and which allows a new didactic experience of dance.

Below is the hypothesis of the structure of the lesson and of the levels.

5.1 Lesson structure and levels

In general, the lesson takes inspiration, for structure and exercises, from the Cunningham Technique, but it borrows some qualities and characteristics of the Release Method such as the principles of fall-recovery-suspension and moments of improvisation.

The choice depends above all on the salient characteristics of these techniques and on how they can integrate with the work of the system.

The Cunningham Technique is suitable for working with a movement analysis system being a technique mostly conceived standing up, a factor that greatly simplifies the capture of movement, and having a structure that schematically crosses the parts of the body and their functional and rhythmic use. The elements borrowed from the Release are instead traits that contribute to giving greater softness to the study, allowing the listening of even less schematic and precise movements.

If the initial part of the lesson is made up of purely technical exercises, the second one foresees a use of space in a creative way, following guided improvisation tasks and in-depth works of motor and emotional qualities, as well as social ones. The aim of the technique, in addition to teaching by means of sonification for the purposes previously described, is to give both technical and creative training, increase awareness and stimulate the search for one's own motor signature through the increase of technical-proprioceptive awareness. For this reason the two aspects are carried out in parallel, although with different durations within the various levels, as well as for the parts of the lesson of the Cunningham Technique.

The lesson in general is structured as follows:

- **PHASE 0:** Short test phase and approach to sound and system, proprioceptive recollection phase, personal analysis of the here and now
- **PART I:** Warm up (Upper body - Lower body)
- **PART II:** Movement in space (Triplets , Adagio, Jumps)
- **PART III:** Creative section / Structured improvisation

It is evident that within the lesson, whose hypothetical duration is about an hour and a half, not all the complete phases can be done, so the content of the individual ones will be modulated according to the objectives of the lesson and the duration of the lessons. according to the level.

The assumed levels are:

  - **Preparatory:** open to children or non-dancers. It is purely based on the exploration of the system and movement through creative processes of guided improvisation. It has a laboratory function.

- **Beginner:** for dancers with little or no technical and sonification experience. Enters the system gradually, starting with the introduction of exercises, mechanics and principles of technique. It is structured in PHASE 0 and PART III followed by PART I and PART II. Suitable for young students, 9/13 years old.

- **Intermediate:** for dancers with technical and medium sonification experience. It inserts the system throughout the duration of the lesson and follows the canonical order. PHASE 0, PART I and PART II remain predominant with respect to PART III which is expanded in Lev. Advanced. Suitable for teenage students, 14/18 years old.

- **Advanced:** for dancers with technical experience. It results more and more in PHASE 0, PART I and PART II to leave more breath to the phase dedicated to improvisation and research, PART III. Suitable for professionals or adult students aged 18 and over.

The content of the lessons is to be considered hypothetical and adaptable to the specific needs of the class, from case to case.

5.2 Simulation

The video presented is a short simulation of how two technical exercises and one improvisation task could work within a typical lesson. In each lesson, depending on the didactic intent, you can choose which parameters of the movement to sonify. (Link to the video: https://youtu.be/j2z0VokYrIg)

Although it is assumed that the system will be able to sonify several parameters of movement at the same time, starting from the four Labanian pillars of WEIGHT, SPACE, FLOW, TIME and reaching even more subtle nuances, it was decided to take as an example a sound display that sonicifies only the weight parameter, which in these exercises results as a salient character, the principle of movement around which the sequences are articulated.

Specifically, this sound display provides, following the verified scheme for the sonification of Lightness of the previously mentioned experiment, "*Does embodied training improve the recognition of mid-level expressive movement qualities sonification*?" (Niewiadomski, Mancini,

Cera, Piana, Canepa, Camurri, 2018) that movements that give the weight downwards correspond to a lower, more serious pitch and to those that bear their weight upwards a higher and feeble pitch, almost like a breath of wind. This short simulation is therefore a small example of how the system could be used, albeit in a partial version, for two technical exercises and a short improvisation session.

The simulation is divided into the representation of three different exercises:

- An exercise of the Cunningham Technique, *"Arm over the head",* focused on warming up the upper body, characterized by a first section strongly composed of rhythmic accents in which the upper body is thrown *"up and over"* to create a curve high, and from a second section in which the torso smoothly and lightly crosses the various positions that make up a complete circle (*Curva alta, Tilt, Arch* and again *Tilt*).

- An Adagio exercise, not coming from the Cunningham Technique but a hybrid between this and the Release Method, which focuses on balanced positions, projected upwards and with a light quality, alternating with upper body *swings, passages in intermediate level* as lunges and second positions in *grand plié,* and level changes of the same pose alternating *plié* and *relevé,* in order to emphasize the lowering or suspension of the weight of the pelvis and consequently of the body.

- An improvisation session that focuses on the alternation of the qualities in question, then suspension upwards and acceleration towards the floor, lightness and weight.

The sounds used in the simulation were created by the composer Andrea Cera, who has worked for years at the Centro Casa Paganini in Genoa and is part of the authors of the article examined (Niewiadomski, Mancini, Cera, Piana, Canepa, Camurri, 2018), in occasion of a previous research work in which the sonification of the same Labanian motor parameter was present : “weight”.

The sounds have been mounted on the movements in a way that is coherent with the idea of operation of the system, in order to make its intentions and the final result that is desired through future developments as clear as possible .

6. **Conclusions**

The paper documented the research path that led to the conception of the system, *Sonified Proprioception Technique - SPT*, which arises as a method teaching dance through *motion capture technologies*, motion analysis and sonification.

In the course of the paper, an attempt was made to analyze the state of the art of sonification and how this can be useful and is already used in various fields of scientific and artistic research, in order to show the spectrum of possibilities of the system hypothesized for methodological purposes.

The study highlighted how sonification can be an effective proprioceptive tool, a means of amplifying one's perception, already in common use in the research field, and verified several times in studies and applications. Sound has proven to be a faithful ally for the perception of movement and its characteristics, as well as the integration between internal and external listening amplifies the possibility of an immersive and interactive environment functional to teaching and the amplification of body awareness.

Numerous examples have been given to corroborate the perceptual path of studies based on sonification systems, focusing on the results and sound characteristics associated with particular movement characteristics in verified studies in order to validate the choices made for the final project in terms of sound display.

The explanation of the final project, Sonified Proprioception Technique - SPT, involves the in-depth study of projects that were founding pillars of its birth in terms of studies and principles, profiling the system's possibilities in teaching and in different fields, from art to science.

The project hopes to make its contribution to the methodology of dance by feeding on a prolific environment that has always taken inspiration from art to develop science, hoping to be able to implement a reverse process in which dance can be learned through the development of scientific discoveries and technologies increasingly optimized for conscious and sustainable human use.

Bibliography

- R.Laban , C. Lawrence (1946) *Effort: Economy of Human Movement* , London; MacDonald & Evans
- R.Laban (1948) *Modern Educational Dance* , London; MacDonald & Evans
- R.Laban (1966) *Choreutics* (with revision and additions by Lisa Ullmann), London: Macdonald & Evans
- Parise, CV & Spence, C. Exp Brain Res (2012) 220: 319. https://doi.org/10.1007/s00221-012-3140-6
- Danna J and Velay JL (2017) On the Auditory-Proprioception Substitution Hypothesis: Movement Sonification in Two Deafferented Subjects Learning to Write New Characters. *Front. Neurosci* . 11: 137. doi : 10.3389 / fnins.2017.00137
- Delle Monache, Rocchesso , Bevilacqua, Lemaitre, Baldan, Cera, (2018). Embodied Sound Design. International Journal of Human-Computer Studies. 118. 47-59. 10.1016 / j.ijhcs.2018.05.007.
- Laeng B, Flaaten CB, Walle KM, Hochkeppler A and Specht K (2021) “Mickey Mousing” in the Brain: Motion-Sound Synesthesia and the Subcortical Substrate of Audio-Visual Integration. *Front. Hum . Neurosci* . 15: 605166. doi : 10.3389 / fnhum.2021.605166
- Saenz, M. Koch, C. (2008). Hearing motion in "the mind's ear" - evidence for a vision-to-sound synesthesia [Abstract]. Journal of Vision, 8 (6): 524, 524a, http://journalofvision.org/8/6/524/ , doi: 10.1167 / 8.6.524.
- Carroll Noël , Moore Margaret, «Feeling movement : Music and Dance», *Revue internationale de philosophie* , 2008/4 (n ° 246), p. 413-435. DOI: 10.3917 / rep. 246.0413. URL: https://www.cairn.info/revue- internationale-de-philosophie-2008-4-page-413.htm
- Hermann T., Höner O., Ritter H. (2006) AcouMotion - An Interactive Sonification System for Acoustic Motion Control. In: Gibet S., Courty N., Kamp JF. (eds) Gesture in Human-Computer Interaction and Simulation. GW 2005. Lecture Notes in Computer Science, vol 3881. Springer, Berlin , Heidelberg. https://doi.org/10.1007/11678816_35
- MOCO '20: Proceedings of the 7th International Conference on Movement and Computing , July 2020, Article No. 7, Pages 1–8, https://doi.org/10.1145/3401956.3404226

- Patania VM, Padulo J, Iuliano E, Ardigò LP, Čular D, Miletić A and De Giorgio (2020) The Psychophysiological Effects of Different Tempo Music on Endurance Versus High-Intensity Performances. *Front. Psychol* . 11:74. doi : 10.3389 / fpsyg.2020.00074

- Ghai S, Schmitz G, Hwang TH, Effenberg AO. Training proprioception with sound: effects of real-time auditory feedback on intermodal learning. Ann NY Acad Sci. 2019 Feb; 1438 (1): 50-61. doi : 10.1111 / nyas.13967. Epub 2018 Sep 17. PMID: 30221775.
- Frédéric Bevilacqua, Eric O Boyer, Jules Françoise , Olivier Houix , Patrick Susini, Agnès Roby-Brami, and Sylvain Hanneton . 2016. Sensors- motor learning with movement sonification : perspectives from recent interdisciplinary studies. Frontiers in neuroscience 10 (2016), 385.
- Antonio Camurri, Corrado Canepa, Nicola Ferrari, Maurizio Mancini, Radoslaw Niewiadomski , Stefano Piana, Gualtiero Volpe, Jean-Marc Matos, Pablo Palacio, and Muriel Romero. 2016. A system to support the learning of movement qualities in dance: a case study on dynamic symmetry. In Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct. 973–976.
- Antonio Camurri, Katerina El Raheb , Oshri Even -Zohar, Yannis Ioannidis , Amalia Markatzi , Jean-Marc Matos, Edwin Morley-Fletcher, Pablo Palacio, Muriel Romero, Augusto Sarti, et al. 2016. WhoLoDancE : towards a methodology for selecting motion capture data across different dance learning practice. In Proceedings of the 3rd International Symposium on Movement and Computing. 1–2.
- Antonio Camurri, Shuji Hashimoto, Matteo Ricchetti, Andrea Ricci, Kenji Suzuki, Riccardo Trocca , and Gualtiero Volpe. 2000. Eyesweb : Toward gesture and affect recognition in interactive dance and music systems. Computer Music Journal 24, 1 (2000), 57–69.
- Antonio Camurri, Gualtiero Volpe, Stefano Piana, Maurizio Mancini, Radoslaw Niewiadomski , Nicola Ferrari, and Corrado Canepa. 2016. The dancer in the eye: towards a multi-layered computational framework of qualities in movement. In Proceedings of the 3rd International Symposium on Movement and Computing. 1–7.
- Niewiadomski , Mancini, Cera, Piana, Canepa, Camurri (2018). Does embodied training improve the recognition of mid-level expressive movement qualities sonification ?. Journal on Multimodal User Interfaces . 13. 10.1007 / s12193-018-0284-0.
- Marco Donnarumma. 2011. XTH SENSE: a study of muscle sounds for an experimental paradigm of musical performance. In ICMC.

- Emanuele Quinz . 2002. Digital performance. Anomos .
- Emanuele Quinz . 2003. Interfaces .
- Emanuele QUINZ and Miguel ALMIRON. 2000. Anomalies in digital arts .
- Bruce NWalker and Michael A Nees . 2011. Theory of sonification. The sonification handbook (2011), 9–39.
- R.Laban , (1999) The art of the Movement, E. Casini Ropa , S. Salvagno, Ephemeria Editore
- Gigi Caciuleanu , (2010), *Vento, volumi e vettori.*
- "Rudolf Laban: body space expression", Maletic Vera, Publisher L'Epos; 26/08/2011
- History of dance and ballet by Ornella di Tondo, Flavia Pappacena, Alessandro Pontremoli; https://www.ibs.it/libri/editori/gremese-editoreGremese https://www.ibs.it/libri/editori/gremese-editoreEditore , 2019
- Oliver Sacks (2010), Musicofilia , Adelphi Editore

Sitography:

- https://entimement.dibris.unige.it/
- ftp://ftp.infomus.org/pub/Staff/AntonioCamurri/2016-IEEE_Multimedia_MM-23-01-Media-PREPRINT.pdf
- http://130.251.14.190/Events/CronacaDelLuogo.html
- ftp://ftp.infomus.org/pub/Staff/AntonioCamurri/2016-MOCO-MovementQualitiesConceptualFramework.pdf
- ftp://ftp.infomus.org/pub/Staff/AntonioCamurri/1986- Dance% 20and% 20Movement% 20Notation.pdf
- ftp://ftp.infomus.org/pub/Staff/AntonioCamurri/2019-JMUI-InteractiveSonification.pdf
- http://dance.dibris.unige.it/ .
- https://interactive-sonification.org/files/deCampo_ISon2007.pdf
- https://openpsychologyjournal.com/contents/volumes/V8/TOPSYJ-8- 192 / TOPSYJ-8-192.pdf
- https://doi.org/10.1111/nyas.13967
- https://www.kennedy-center.org/education/resources-for- educators / classroom-resources / media-and- interactives / media / dance / music-as-dances-muse /
- https://bibliolmc.ntv31.com/node/1658

- https://www.eai.org/titles/variations-v
- http://www.wholodance.eu/
- http://www.casapaganini.org/atempo/