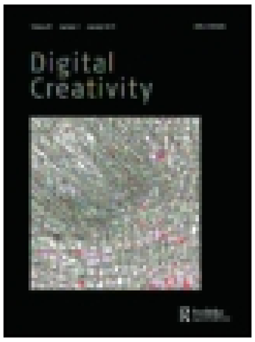

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Using mobile sound to explore spatial relationships between dance and music performance

Felipe Otondo

Institute of Acoustics, Universidad Austral de Chile, Valdivia, Chile

ABSTRACT
The availability of robust and cheaper hardware tools in recent years has allowed the possibility of effectively integrating spatial sound as an organic component of dance and music performance projects. Inspired by these recent developments, an original body-worn sound system was designed, implemented and acoustically optimized aiming to effectively integrate performers' movements and amplified sounds on stage. An innovative acoustic measurement method was used in connection with tests and interviews with practitioners to assess various sonic and artistic features of the implemented sound vest prototype. Audience questionnaires were employed to assess the perceived acoustic performance of the system in a medium size dance studio. Survey results showed that the perceived acoustic performance of the sound vest is highly dependent on the types of sound materials radiated by the system, as well as on the position of the performer in a room. Future work will consider the implementation and assessment of an extended hybrid spatial system consisting of several mobile sound sources synchronized with a fixed multi-channel sound reproduction system.

KEYWORDS
Mobile music; digital performance; dance; spatial sound; wearable space

1. Introduction

Space is one of the most intuitive and salient features of dance and music performance (Brant 1967; Musgrave 1974; Globokar 1980; McAuley 1999; Tufnell and Crickmay 2001). Composers and dancers have always collaborated trying to find suitable ways of relating musical and choreographic materials on stage (Lanzalone 2000, 18; Cavalli 2001, 4; Stiefel 2002, 3; Birringer 2010; McLean and Sicchio 2014, 356). In the last decades, the traditional role of sound in dance performance, where static sound sources are located off-stage, has been slowly changing in order to incorporate innovative spatialisation methods aiming to locate and spatialize electronic sounds which are carefully integrated as part of gestures and actions on stage (Hahn and Bahn 2002, 230–232; Birringer and Danjoux 2009, 96; Otondo 2010a, 3; Wilkins and Ben-Tal 2010, 19). The availability of cheaper and robust mobile sound systems has allowed performers and technology developers to design and implement standalone wireless systems that can easily be adapted to the requirements and needs of different kinds of performance environments and audiences (Stahl and Clemens 2010, 429; Birringer and Danjoux 2013, 232, 2014, 9–10; Weismann 2015). Taking into account some of the acoustic and practical limitations of these mobile sound

CONTACT Felipe Otondo felipe.otondo@uach.cl Instituto de Acústica, Universidad Austral de Chile, Casilla 567, Valdivia, Chile
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systems on stage, it was decided to design and implement an original wireless body-worn sound system that could be easily adjusted to the requirements of dancer and musicians in different kinds of performance circumstances (Otondo 2015, 310–311). The main motivation of the research project was to design a wearable sound device that would be capable of effectively radiating sound in small and medium-size performance venues, but at the same time flexible enough to allow performers to carry out conventional dance movements in standing and floor positions. In this case the intention was to provide a transdisciplinary framework where by means of acoustic measurements, interviews and audience surveys one could approach the complex phenomenon of the use mobile sound sources for performance purposes. This approach was inspired by Henry Brant's studies involving travelling musicians and singers in the 1960s and 1970s (Brant 1967, 221). Brant's pioneering research led to the idea that the best way to approach spatial sound in performance is by developing a holistic strategy that would take into account the nature of spatialized sound in a hall on the one hand and the listener's experience of directional and mobile sound sources on the other.

After various pilot tests and adjustments to several prototypes, a sound reproduction system to produce pre-recorded audio files was implemented incorporating a loudspeaker unit in the front of the performer's torso, two loudspeaker units located on the arms of the performer, a two-channel Maxim 25 Watt amplifier fed by 12 Volt batteries and a two channel 2.4 GHz Bluetooth transmitter with a receiver set (Otondo 2015, 345–346). Placing a central speaker on the torso of the performer was intended to provide a stable sonic reference on stage, while the role of speakers on the performer's forearms was to provide variable sound diffusion related to arm gestures controlled by the performer as sound beams. This article discusses the assessment of the implemented system vest taking into account artistic, practical and technical issues involved in dance and music performance.

2. Measurements and pilot tests

2.1. Acoustic camera measurements

As documented in a previous publication, frequency response and acoustic power measurements of individual components of the designed body-worn system were carried out to in an anechoic chamber (Otondo 2015, 342). These measurements provided a reasonable overview of the acoustic performance of isolated components of the sound vest, but little information about the response of the system when used by a dancer in a realistic performance situation. It was therefore decided to measure the overall performance of the system when used by a dancer by utilizing an imaging device that allowed the possibility of characterizing sound sources in real-time during a short dance demonstration in an anechoic chamber. The system used for this purpose was an acoustic camera Ring 48–75 ACPro with a 48-microphone array and a beamforming method (Acoustic Camera 2017) to simultaneously acquire data and visually localize acoustic emissions of sound sources (Otondo 2016, 291). Figure 1 shows a dancer wearing the sound vest during the acoustic camera measurements carried out at the large anechoic chamber of the Institute of Acoustics at Universidad Austral de Chile.

The purpose of these measurements was to get a realistic illustration of acoustic power, frequency response and directivity variations of the system when worn by a performer during a short dance demonstration. The first stage of measurements involved a demonstration of the body-worn sound system radiating sounds with the performer in various static dance positions for 10-second periods. The two audio channels of the system (channel 1: torso and channel 2: arms) were measured independently and simultaneously. The second stage of

Figure 1. Acoustic camera measurements of the body-worn sound system worn by a dancer during demonstrations in an anechoic chamber.

measurements was conducted while the performer carried out a series of slow movements in front of the acoustic camera, as shown in Figure 2. Two types of sound materials were used to feed the body-worn system for the acoustic measurements: generated white noise and recorded bell sounds. This decision was based on pilot tests carried out with the system in various rooms. These showed that, due to the size and frequency response of the loudspeakers used in the torso and hands of the performer, this kind of sound materials provided the best possible radiation performance in terms of acoustic power and frequency response in dance halls. These sounds were used as raw material to compose short test tracks, which were also used as the basis for the pilot tests and the demonstration with audiences, which will be discussed below. Measurement results showed a complex and fluctuating acoustic field which to some extent can be roughly related to the acoustical behaviour of individual components measured independently in the study mentioned above (Otondo 2015, 342). Figure 3 shows the radiation pattern of the sound vest during the performance of simple dance movements in the anechoic chamber. The top figures show the sound field generated by the torso loudspeaker and the figures below show the acoustic sound field generated by the arm loudspeakers radiating white noise. During the dance demonstrations the measured sound field generated in front of the camera exhibited dramatic intensity variations, which roughly related to the radiation and frequency response of the torso and arms' loudspeakers measured in the study mentioned above (Otondo 2015, 343–344). In line with results from previous measurements, acoustic camera measurements showed that there is a considerable acoustic power difference between the arm and torso loudspeakers, with the paired arm loudspeakers considerably louder than the single torso speaker (Otondo 2015, 346). Showing a similar tendency to previous frequency response measurements, in this case results showed that the torso and arms loudspeakers exhibited a very different acoustic performance over 5 kHz, with the arm speakers' response much smoother in the 5–12 kHz range. Acoustic

Figure 2. Measurements of the body-worn sound system during a dance demonstration carried out using an *Gfai Tech Ring 48–75 ACPro* Acoustic Camera. Top measurements were done with the torso speaker radiating white noise, while bottom measurements were carried out with the arm speakers also radiating white noise.

camera measurements also showed dramatic directivity changes related to the performer's movements. As shown in Figure 3, when using the sound vest, the performer's body becomes a complex sound source that masks or accentuates particular sounds depending on the specific position of his arms and torso. Top figures display the radiation of the individual torso speaker and bottom figures show the radiation of the arm speakers when using

Figure 3. On-location pilot trials of the system with dancer, choreographer and composer in a dance studio.

white noise signals as inputs to the system. The particular acoustic features of the system discussed above have a direct impact on the perceived sound by audiences and performers in a performance space, as discussed below.

2.2. In-situ tests with a dancer

Following the acoustic camera measurements, pilot tests of the body-worn sound system were carried out in a dance studio where various types of movements and sound materials were tested with the help of a choreographer and a dancer. Figure 3 shows the dancer during tests of system in a dance studio joined by the choreographer and the author. The main goal of these tests was to carry out a realistic in-situ assessment of the main acoustic features of the sound vest and also to gather feedback from the dancer, choreographer and composer on how to improve the system before testing it in front of an audience. The tests were recorded with a video camera and a stereo microphone and were later used for the detailed analysis by the team, as discussed below. The first tests that were carried out focussed on assessing the flexibility and comfort of the system from the point of view of the performer. A set of basic dance movements was designed in collaboration with the choreographer in various static positions in the room, followed by a series of movements to be performed across the studio. The main problem detected with these tests was that the hardware components and cables on the torso and hands of the performer were not tightly fastened to his body, thus limiting the dancer's freedom for floor movements. After a series of discussions with the dancer, the choreographer and an assistant student, it was decided to provide more robust adjustments of the straps that support the various hardware components of the system, as well as a new set of cable connectors to increase the stability of the wireless Bluetooth transmission chain. Adjustments to the shape and position of hardware components of the vest were also made in order to add flexibility for the performer and increase the robustness of the system when performing floor dance movements. The adapted system allowed the dancer to add a greater range of floor movements and react faster to changes in the sound material played through the loudspeakers on his body. As discussed below, the impact of these changes on the range and quality of the movement material created by the dancer using the system proved to be one of the most original and surprising contributions of the project. The second series of tests, which were carried out to assess the acoustic response of the sound vest in the dance studio, involved the use of two predetermined types of sound materials as inputs to the system: short composed audio tracks of white noise and recorded bell sounds. The decision to use these two kinds of sound materials was based on similar tests carried out by Hahn and Curtis with interactive wireless systems (Hahn and Bahn 2002, 232) and on their contrasting acoustic and directional properties that can be related to multichannel spatialisation techniques used in electroacoustic music (Stefani and Lauke 2010, 252). This technique was first tested with audiences in a performance project involving the use of mobile sound at the Edinburgh Fringe Festival with very positive results (Otondo 2010a, 1). In order to evaluate the system under different kinds of circumstances, two types of assessment approaches were used. The first were in-situ tests in a small dance studio that involved the choreographer, the dancer, the author and three postgraduate students. Each participant took notes after two short demonstrations of the system using both types of sound materials and two contrasting choreographies. Individual notes from each participant were discussed and summarized after each test. The second approach involved the use of video footage of the demonstrations in connection with the tests mentioned above. The obtained video recordings were later carefully analysed by the author and two postgraduate research students and helped to clarify comments by the choreographer and dancer regarding the role of sound materials in relation to specific movements. In line with similar tests carried with other spatialisation sound systems, results from the analysis of tests carried out using the sound materials mentioned above indicated that the perceived directivity, intensity and sound quality of the sound vest in the studio were very dependent on the timbral and dynamic qualities of the sounds used (Stefani and Lauke 2010, 52; Baalman 2010, 209–210). On the one hand, white noise signals were perceived as much louder than bell sounds when using the same electrical output of the system. On the other hand, due to their high frequency timbral qualities, bell sounds were perceived as much more directional, focussing on the specific locations of the performer's body. In both cases, the same signals were fed into the arm and torso loudspeakers using two specific high-pass filtering processes to avoid sound distortion. It was also evident during the tests in the dance studio that the prominent directivity of the system for specific frequencies had a direct impact on the way the dancer approached the designed choreography in terms of quality and amount of generated movement material. It was apparent that the position of the loudspeakers on the performer's body and the particular frequency radiation features of the system incited the performer to adapt the choreography, exploring the surrounding acoustic space by masking or accentuating radiated sounds with the positions of his arms and hands. This issue was discussed with the performer who acknowledged the fact that the reflected sound from the surrounding walls had a direct impact on the sequence of decisions made during the development of the demonstration. In this case, the localization of sound sources on the performer's body allowed him to redirect reproduced sounds in specific directions like light beams. Even though the performer had no control over the type of sound materials reproduced through the system, the localization of speakers on specific parts of the body allowed him to control to a high extent the volume, timbre and spatial attributes of the radiated sounds. As discussed below, this fact had a direct influence on the way sounds and movement gestures were perceived by audiences in a performance space. As discussed below, it was also clear that raw sounds with little or no processing gave more freedom to the performer, allowing him to play a more active role in the overall sound design. The performer also reported that the vibration of the various devices on his body motivated him to move faster or slower, depending on the intensity and frequency of the reproduced sounds. At some point of the trials the performer reported having been slightly overwhelmed by the intensity of these vibrations on his body.

The composer also played an active role during the tests with the dancer by designing, adjusting and balancing the sounds reproduced through the torso and arms' speakers. As in similar interdisciplinary projects involving state of the art wireless sound technology, initial tests during rehearsals considered reproduced sounds that were carefully composed using intricate timbral and spatial sound processing techniques (Stahl and Clemens 2010, 429; Wilkins and Ben-Tal 2010, 21–22). After some tests with the system playing these composed sounds while the performer made some simple movements, the panel observed that sounds were not reproduced in an effective and clear way through the system. The main reason for this was the fact that the performer's movements created an extra layer of timbral and spatial articulation on the sound material fed into the system. In line with Hahn and Bahn findings (2002, 232), it was decided to use raw sounds with little or no processing, which produced a much clearer sound diffusion in terms of timbral and spatial clarity. In line with findings by Wilson and Bromwich (2000, 10–11) and Vincs and Barbour (2014), further developments of the system will consider an interactive feature involving movement sensors that will allow the dancer a more direct control of the timbral and spatial attributes of the radiated sound materials. Such an improved system should enhance the relationship between visual and sonic material, adding a new creative dimension to the project.

3. Interviews with practitioners

As a way of assessing the attributes and limitations of the body-worn sound system in a realistic performance environment, interviews with performers and choreographers involved in the project were conducted. The first interview was carried out with the choreographer Francisca Morand during the early stages of the pilot tests mentioned above. Morand is actively engaged as a teacher, choreographer and performer in interactive dance projects involving the use of state of the art software and hardware technology (Gómez and Jaimovich 2016, 305; Jaimovich 2016, 316). A short dance demonstration of the system was carried out by a dancer for Morand in a studio using sound and movement materials similar to those used for the measurements and pilot tests discussed above. After the demonstration a short interview was carried out in which Morand commented on two issues related to the performance of the system. In line with the discussion about the quality and nature of reproduced sounds through the body of the performer mentioned above, the first issue raised by the interviewee was the importance of clarifying sound materials in relation to basic movement materials as a way of establishing a basis for spatial relationships on stage that the audience could follow. Morand's experience in projects involving the use of different kinds of movement sensors is that, if sound materials are simplified, the choreographic materials should also be streamlined in order to allow the audience to grasp these relationships. This idea is based on the fact that a dancer radiating sounds on stage is *per se* a complex sensorial experience for the audience, resulting from a unique combination of acoustic, perceptual and kinetic qualities.

The second issue raised by Morand was the importance of taking on board the experience of the dancer into the implementation of the system. As shown in a similar project involving dance and technology (McLean and Sicchio 2014, 356), she noted that in this case it is obvious that the use of the device considerably affects the way the dancer moves on stage and therefore how she/he relates to an audience. In her opinion, this added spatial sonic element becomes the most salient and at the same time challenging feature of the project.

After a series of rehearsals and pilot tests carried out in a dance studio, interviews were also conducted with the dancer and another choreographer involved in the project. The interview with the dancer Germán Mora focused on various issues related to the performer's experience when using the sound vest. Asked about the challenges of using the system during a performance, Mora commented that, initially, it had been a slightly unusual experience to dance with extra weight on his body, but gradually he got used to it and adapted his movements to the shape and weight of the device. He noted that the issue of being aware of carrying delicate equipment on his body also had an impact on the type and range of movements he used, especially for movements where the performer had to roll over with his back towards the floor. Regarding the creative possibilities of the system, Mora was keen to emphasize the importance of embracing a new role as a performer/musician that radiates sounds into space:

> The creative possibilities of the system are wide-ranging, mostly because one has the chance to experiment with the projection of sounds, becoming quickly aware that movements have a direct impact on the audience, not only from a visual, but also from an acoustic perspective. By using the sound vest in different types of acoustic spaces, I was gradually able to assimilate the creative possibilities of spatial sound.

Mora also pointed out the importance of the performer being aware of the artistic implications that the use of the device has on the audience:

> you become much more aware that the audience in not only looking at you, but also listening to the sounds that you are producing with your body. The audience becomes rapidly used to the fact that in this case the sounds are not coming from fixed loudspeaker positions outside the performance area, but from mobile sound sources close to them.

As mentioned above, one of the important issues concerning the design and implementation of the body sound system was the possible impact that vibrations and high sound levels could have on the dancer when using the sound vest. When asked about this issue, Mora noted that, in his case, vibrations had a positive impact, because they allowed him to feel the music in a different way during the performance; additionally, when the system was reproducing intense sounds he could easily adjust his arms and body to mask these sounds and therefore prevent close contact with his ears. In his opinion, this also has a positive effect on the performer because it makes him/her more aware of the body to explore new possible relationships with an audience.

A second interview was carried out with the choreographer involved in the project Ricardo Uribe. Asked about the creative possibilities of the sound device, Uribe pointed out that one of the most interesting aspects of the interface was that it allowed the performer the unusual possibility of projecting sounds freely into the performance space. He believes that the dancer's possibility to direct radiated sounds in connection with specific movements adds to the dance a different meaning. This allows the choreographer the possibility of developing movement in a different way, opening up a range of new dynamic relationships between sound and movement.

Asked about how this affected the choreography, Uribe pointed out that in this case the choreographic design had to adapt to a new challenge:

> In dance performance sounds are, in most cases, conceived by performers as something external and they learn how to develop a relationship with these exterior sounds. In this case, due to the fact that sounds are transmitted directly from the dancer's body, the performer has to construct a new relationship with these sounds and conceive new strategies to approach the dance.

Asked about the limitations that the system can impose on performers, Uribe believes that, while there are some obvious kinetic limitations posed by the system on the dancer, these restrictions can also become an opportunity for the performer to become more conscious of the sonic implications that his/her movements can have on an audience. Asked about how the system might be perceived by audiences during performances, Uribe noted that, in most cases, spectators are curious of technological tools integrated as part of the dance performance and that the sound vest can enhance a unique and unusual relationship between performers and audiences. To give an example, he mentioned a rather unique acousmatic experience for the audience that took place when the dancer moved to the back of the hall during demonstrations of the system with a few colleagues and students. In this case, the same sounds, heard initially as part of dance gestures in front of an audience, were later presented as disembodied sounds projected from the back of the room, creating a striking immersive aural experience similar to a multichannel electroacoustic music concert where sounds are carefully spatialized with loudspeaker arrays around the audience (Otondo 2008, 78; Stefani and Lauke 2010, 252).

4. Audience survey and open discussions

4.1. Questionnaire design

Taking on board the information gathered from the measurements, tests and interviews discussed above, a short survey was designed to assess the impact that the body-worn sound system could have on dance audiences. The main goal of the survey was to evaluate in-situ the perceived acoustic performance of the sound system in terms of reproduced sound quality and radiated power. In this case, sound quality was related to perceived timbral quality and radiated power to sound intensity perceived by the audience. A second goal was to assess the impact that the mobile sound system could have from the point of view of a dance audience. A short questionnaire was therefore designed focusing on three main topics: (1) perceived acoustic power, (2) perceived sound quality and (3) favoured positions of the system in the room during the demonstration. Four short dance demonstrations were carried out by the performer in a 110 m^2 dance studio at Valdivia's Local Town building. The audience consisted of 19 adults related to dance performance, predominantly dance students, choreographers, university students and artists from various backgrounds. Short dance demonstrations were designed and implemented by the choreographer Ricardo Uribe and the dancer Germán Mora using similar movement materials to the ones considered for the measurements and pilot tests discussed above. The demonstrations took place in two main areas in the hall: traditional frontal position across the stage and movements around the audience seating area. Figure 4 shows the two areas where demonstrations were carried out by the dancer and Figure 5 shows audience surveys taking place after demonstrations in the hall. Two types of sound materials were tested for the two areas in the room resulting in the four short demonstration examples shown in Table 1. After each short demonstration, members of the audience were asked to answer the following three questions:

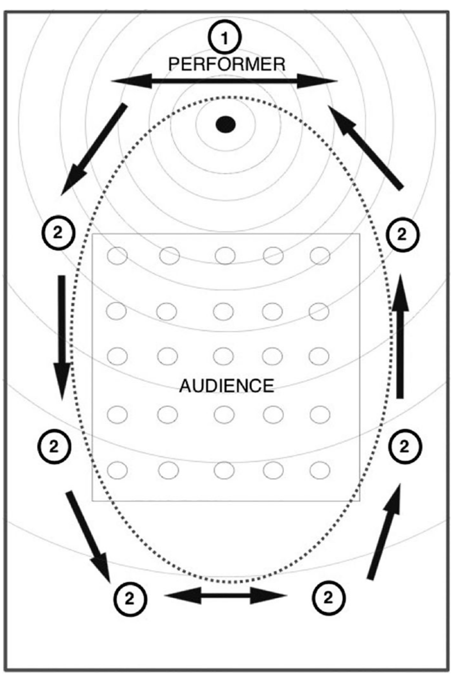

Figure 4. Performer positions during the dance demonstrations of the body-worn sound system with an audience. The first position is across the stage (1) and the second position involved movements around the audience seating area (2).

(1) How would you rate the sound level of the vest system during the demonstration?
(high, acceptable or low)
(2) How would rate the quality of the sound radiated by the vest system during the demonstration?
(good, average or poor)
(3) In your opinion, in what part of the room did the sound vest worked best?
(front, around, behind or when moving).

4.2. Survey results

The results of the survey were collected and analysed for each question, as shown in the tables below. Results for the first question

Table 1. Dance demonstration carried out with two types of sound materials in two positions in the hall.

Demonstration	Sound material	Performer's position
1	Noise	Front (position 1)
2	Bell sounds	Front (position 1)
3	Noise	Movements around the audience (position 2)
4	Bell sounds	Movements around the audience (position 2)

Figure 5. Audience surveys carried out after dance demonstrations of the body-worn sound system at the dance studio of Valdivia's Town Hall Building.

regarding the perceived sound power of the system by the audience (see Table 2) indicated that, when using the noise sounds, the system was perceived differently in front of the audience when compared with various positions around the audience. In the case of the bell sounds, this difference was considerably less dramatic. In general terms, the perceived sound power of the body-worn sound system was rated as 'high' in most cases, which indicates that the system has more than enough acoustic power to cover a medium-size performance space. When looking at the results of the perceived sound quality of the sound system (see Table 3) figures are more consistent. For both types of sound materials results are similar, the perceived sound quality of the system in most of the cases being rated as 'good' and in a few cases as 'regular'. Results regarding the performance of the system in the room (see Table 4) indicated that the frontal and rear positions in the hall were rated similarly low, with only 11% of the audience considering, in both cases, that these were the positions in which the system had the best performance. Rather surprisingly, the most popular position in the room was around the audience with almost half of the respondents' preferences. Nearly one third of the respondents considered that the best performance of the system was when the dancer was moving in the hall.

Overall, the survey results provide preliminary evidence to suggest that: (1) the maximum acoustic power of the system is suitable for small and medium size dance studios, (2) the quality of the perceived reproduced sound is

Table 2. Perceived acoustic power of the body-worn sound system during the dance demonstration.

Perceived acoustic power	High (%)	Medium (%)	Low (%)
Noise – frontal	47	53	0
Noise – around the audience	68	32	0
Bell sounds – frontal	84	16	0
Bell sounds – around the audience	74	26	0

Table 3. Perceived sound quality of the body-worn sound system during the dance demonstration.

Perceived sound quality	Good (%)	Regular (%)	Poor (%)
Noise – frontal	68	32	0
Noise – around the audience	63	32	5
Bell sounds – frontal	74	26	0
Bell sounds – around the audience	74	26	0

Table 4. Best perceived performance of the body-worn sound system in different positions in the room during the dance demonstrations.

Best perceived performance of the system	In front of the audience (%)	Around the audience (%)	Behind the audience (%)	When moving (%)
Position in the hall	11	47	11	31

very dependent on the type of sound material fed to the system and (3) the impact of the system on audiences is very dependent on the position of the performer in the hall, the preferred positions being around and close to the audience seating area. Other conclusions and ideas related to the performance of the system are discussed below.

4.3. Open discussions with audiences

After the surveys were carried out an open discussion with the members of the audience took place. These discussions were recorded on video for further analysis. The main goal of these discussions was to allow the public to freely provide opinions or ask questions about the system after the demonstration. A wide range of questions and opinions were presented by a diverse audience, which included choreographers, engineering postgraduate students, dance students, musicians and an architect. The issue that concentrated most comments during the discussion was the impact that the system had on the performer during the demonstration. The artistic and physical impact of the system on the dancer during the performance was discussed extensively by participants from various perspectives. Dance professionals involved in the discussions agreed that the system could be improved in order to allow more flexibility for the dancer and also increase the artistic possibilities of the system as a whole. The next topic discussed during the discussions was the issue of the directional attributes of the system. In line with the acoustic measurements discussed above, participants felt that the system performed spatially in a completely different way with noise broad band signals (omnidirectional) compared with the bell sounds (very directional). The importance of the acoustic power of the system was also mentioned in this context. Most participants agreed that with both kinds of sound materials the dynamic range of the system was more than enough for the medium-size hall where the demonstration took place. The impact of the type of radiated sound material was also mentioned in connection with the directivity of the system. Most participants preferred the bell sounds to the noise due to their subtle and adaptable attributes which were easy to adapt to the dancer's movements.

5. Discussion

Measurements, tests, interviews, surveys and open discussions with audiences involving the use of the sound vest provide pilot information that indicates that the system has potential to become a highly expressive creative tool that can be adapted to the needs and requirements of various types of performance situations. One of the more significant findings of the activities discussed above is that the sound vest allows the possibility of establishing new relationships between audiences, choreographers, composers and performers. The embodiment of sounds, on and off-stage, allows traditional interactions between dancers and sound sources in a hall to be enhanced by allowing more direct and intimate interactions between dancers and spectators (Birringer 2010, 102; Otondo 2010b, 448; Birringer and Danjoux 2014, 111). Open discussions with audiences after demonstrations of the system showed that, most of the time, spectators are very eager to explore new ways of interacting with performers on and off-stage and therefore welcome the use of new technologies that can expand creative interactions within a dance performance context. These discussions also showed that the system is perceived in very different ways by members of the audience. Results and discussions also showed that conventional audience shoebox seating arrangements like the ones used for the survey demonstrations do not seem to be fit for this purpose because they tend to restrict the space for interactions between performers and spectators. Future developments of the projects will explore the use of different types of audience seating dispositions that could eventually enhance visual and sonic interactions on and off-stage (Stefani and Lauke 2010, 253–255).

Another interesting feature of the system which was discussed with colleagues and audiences after demonstrations was the strong potential of the sound vest as an innovative compositional tool. Considering the findings discussed above, two main creative features of the sound vest can be highlighted. The first one is that, in order to make the sound vest radiate sounds effectively in a performance space, sound materials fed to the system need to be carefully selected and tuned to the acoustical properties of the system as discussed in a previous publication (Otondo 2015, 343). Pilot tests with performers showed that raw sounds, with little or no processing, work much better on the system than elaborated sounds with an intricate timbral or spatial design. This phenomenon relates mostly to the size of the speakers on the vest and the complex acoustic phenomena created by the movement of the sound sources attached to the body of a performer. In this case, the dancer movements shape the projected sounds, adding distinctive dynamic, timbral and spatial characteristics to the sonic output through a complex filtering process related to the speed of movements and the position of loudspeakers on the body of the performer from the point of view of the spectator/listener. Another important creative feature of the body-worn sound system is the acousmatic effect that can be created on audiences when the performer is out of sight, mentioned by Uribe at the end of the interview. Memories and recollections of sounds originally heard embodied on the performer can become powerful narrative or dramatic musical effects during performances. This issue was passionately debated after demonstrations of the system in open discussions with audiences and dance practitioners. While most people enjoyed the acousmatic effect produced by the disappearance of the performer in the back of the hall, some people considered the situation slightly confusing and disorientating, probably due to the perceptual implications of sounds heard from behind in a concert hall, as mentioned by Wishart (Wishart 1996, 199–200).

6. Conclusion

The use of mobile sound as an organic component of performing arts projects can enhance the development of new ways of communication between audiences, dancers, choreographers and composers. This study has showed that carefully designed sounds radiated through mobile sound sources on stage can effectively enhance the experience of the audience, opening new perspectives for creating more engaging experiences for dance and theatre spectators. The integration of multi-channel systems and the well-established spatial composition techniques of electroacoustic music within dance and theatre performance practice could effectively enhance and improve the experiences of the audience, by adding a new and immersive feature to the presentation of works in performance halls or site-specific projects (Baalman 2010, 217; Stefani and Lauke 2010, 258). In this line, future developments of this project will explore the use of one or two body-worn sound systems in connection with two, four and eight channel loudspeaker systems as an extended hybrid performance system suitable for different kinds of performance environments. Early tests with performers using commercial wireless loudspeakers synchronized with fixed sound sources on stage suggested that hybrid multi-channel system could allow the possibility of creating a truly immersive sonic environment for performers and the audience, where real and virtual sound sources can be effectively combined on and off-stage (Otondo 2010b, 448; Wilkins and Ben-Tal 2010, 22). Such an extended creative platform could expand the boundaries of performing arts and dance performance by proposing new ways of transforming action into meaning on stage (Hahn and Bahn 2002, 237).

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Notes on contributor

Felipe Otondo studied composition at the University of York in England with Ambrose Field and Roger Marsh focusing on electroacoustic composition and music theatre. His music has been widely played in festivals across Europe, North and South America and has received awards and prizes in composition competitions in Austria, Bulgaria, Brazil, Czech Republic, France, Italy and Russia. Felipe is currently a Senior Lecturer at the Institute of Acoustics at Universidad Austral in Chile and his music is released by the British label *Sargasso*. More information at: http://www.otondo.net

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