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Posted Date: 16 May 2023

doi: 10.20944/preprints202305.1100.v1

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Abstract: Preserving the Intangible Cultural Sound Heritage of Humanity is a crucial aspect of safeguarding a people's culture and history. By employing objective acoustic and psychoacoustic parameters, we can effectively analyze and characterize these auditory environments based on objective, aesthetic, and emotional criteria. The ISO 12913 standard governs the depiction of soundscapes, while the evaluation of outdoor sites involves conducting sound-walks. This study focuses on assessing different soundscapes observed during festivities in Spain as sound walk (dynamic) and as in fireworks (static). The festivities assessed were: "Fallas" in Valencia, Sanfermines in Pamplona, "Festa de la Mare de Deu" in Algemesi, and "Moros y Cristianos" in Villena. To evaluate these soundscapes, we captured ambient sound recordings while traversing through or staying between the festival crowds. Subsequently, we employed various psychoacoustic metrics, such as loudness, sharpness, roughness, fluctuation stress, and tonality, and analyzed them using Zwicker models. Additionally, we conducted a subjective survey to compare the subjective responses with the psychoacoustic metrics obtained.

Keywords: psychoacoustic annoyance; sestive soundscapes; cultural heritage; ISO 12913

1. Introduction

The depiction and subjective assessment of diverse acoustic environments plays a crucial role in shaping activities within a particular setting, influencing the perception of pleasant or uncomfortable experiences. Psychoacoustic parameters serve as valuable tools for evaluating sound perception, and extensive research has been conducted in this field over time. Standards exist for calculating certain psychoacoustic parameters and evaluating subjective annoyance or soundscape quality, as outlined in references [1–3].

Increasingly, popular festivities are being recognized as intangible heritage of humanity by UNESCO, given the importance of identity in the countries that celebrate them. The preservation of this cultural heritage requires capturing the reality of both the visual and the sound components; it would even be desirable to incorporate other senses such as smell and taste. In this work, we are going to approach the characterization of 4 sonorous events, corresponding to Spanish Popular Festivals internationally recognized for their interest as intangible heritage of UNESCO as well as for the manifestation of the feeling of a people. Specifically, we are going to focus on the *Fallas* in Valencia, the *Mare de Déu de la Salut* in Algemesí (Valencia), the *Moros y Cristianos* in Villena (Alicante) and the *Sanfermines* in Pamplona (Navarra).

 doi:10.20944/preprints202305.1100.v1

A common element to these emblematic festivities in Spain is that they are mainly held in the street with very large citizen participation, the use of pyrotechnic elements and music in the street. We will briefly comment below on the differentiating aspects of these 4 festivities.

The *Fallas* in Valencia have their origin in the bonfires that were burned on the eve of the spring equinox and were developed in honour of St. Joseph, patron saint of carpenters. In the 18th century, the bonfires were transformed into constructions that are currently gigantic handmade monuments with figures of extraordinary artistic quality, made of cardboard, wood and other elements of easy combustion since they will be burned at the culmination of the festival on March 19. Throughout the city 700 *fallas* are erected, (350 major and 350 minor -*infantiles*) and have a character of social and political criticism, which seeks purification by fire. These festivities are impregnated with sound activities such as the music bands that accompany all the parades that the members of the 700 *fallas* perform in the city of Valencia, but its main feature was the pyrotechnic sound of fireworks *castells*, *correfocs* (literally in English "fire-runs") and overall the *Mascletà*. The sound of the *Mascletà*, in particular, is a unique and unforgettable experience, with the percussive explosions creating a visceral and powerful sensation that is difficult to replicate.

The *Moros y Cristianos* festivities are a popular Spanish festival celebrated mainly in the south of the Valencian Community and other areas of south-eastern Spain. According to tradition, these festivities commemorate the battles between Christians and Muslims (called "Moors"), Turkish pirates and Barbary pirates between the 8th and 17th centuries, a period in which, in some cases, already have their origin the dawn of this celebration. Specifically, in the case of Villena, the religious celebration is dated 1474, although the civil and military parades are from the second half of the nineteenth century when they started to be celebrated with the same format and structure with which we know them today.

With big or small differences, this celebration is composed of different acts, among which invariably are the Entries (or *Parades*), Embassies and the Procession (usually linked to the feast of the patron saint of the city or town concerned). The participants are divided into two sides, Moors and Christians, dressed in a way that seems to correspond to the medieval period of each culture, leaving, however, much room for fantasy ornamentation. The parades are carried out in rows *filaes* of between 6 and 8 people. The visual component of the festival stands out for its spectacularity, not only for the pomp of the costumes but also for the participation of floats and mounted animals, such as horses, elephants, and dromedaries. The sound part of the festival stands out, (in addition to the specific music of the Moorish and Christian groups, played by the bands, *dulzainas* and percussion groups that accompany the parades of each group), by a large amount of gunpowder used, sounds of muzzle flashes as *arquebuses*, *espingardas* and blunderbusses and the representation of the ancient texts in which words are exchanged between the defenders and attackers. These festivities are celebrated on different dates depending on the locality and the ones we present here, corresponding to the city of Villena, are from September 4th to 9th.

The festivities of the *Mare de Déu de la Salud de Algemesí* (7th and 8th September) date back to the thirteenth century and are one of the most unique celebrations in the province of Valencia. The representations of human towers, theatre, dance, and music that take place, are part of a set of traditions that are passed down from generation to generation, with a large popular participation of the neighbours, as in the processions parade more than 1,400 people. The visual component of the festival corresponds to the environment in which it takes place, between the Basilica of *San Jaume*, the Plaza Mayor and the *Capella de la Troballa*, the parade of the *Verge de la Salut*, the traditional dances (dances of *bastonets*, *pastoretes*, *carxofa*, *arquets*, *llauradores* and *tornejants*) and the spectacular human towers of the *Muixeranga*. The sound component of the festivities begins with the ringing of the bells of the Basilica of *Sant Jaume* that accompanies the departure of the Virgin and the music that accompanies both the dances and the formation of the towers. The clamour of the people who participate is also an element that makes up the soundscape of this festival and that in some ways resembles that of the *Sanfermines*, which we will discuss below.

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The *Sanfermines* is a traditional festival that takes place in the city of Pamplona, every year from July 6th to July 14th. This is a tradition born in the Middle Ages, there are records since 1592. The festival begins with the launching of a gunpowder rocket *chupinazo* in a crowded square and ends in the same square on the 14th where the popular song *Pobre de mi* is intoned. The most characteristic element of these festivities is the running of the bulls, in which the bulls leave the corrals and run about 825 m to the Pamplona bullring, where they are locked up again until the afternoon bullfight. The people who participate in the running of the bulls run ahead of the group of bulls, and any kind of animal abuse is forbidden. Although this is the best-known act of the *Sanfermines*, the sound in *Sanfermines* is a fundamental part of the festival experience and contributes to the unique atmosphere of the event which includes multiple manifestations of popular tradition, mainly traditional dances (*dantzaris*), official acts (parades, *Riau-Riau*), a multitude of musical groups in the street (*Txarangas*) etc, all of which contribute to the soundscape of the event, with the common denominator of being all of them multitudinous acts with great popular participation.

As can be appreciated, they are four very different types of festivals in their visual component, which take place at different times of the year, but have in common, the music in the streets, the use of gunpowder in various manifestations and especially the popular participation that makes all of them a soundscape, that we must not only define and accommodate to the existing acoustic parameters that allow us its quantitative evaluation, but we must also look for new psychoacoustic arguments linked to the emotions perceived by the listeners, which we already know are linked to their moods and memories of space and visual environment.

Various studies have explored the characterization of soundscapes during popular festivities. In the study by Gonzalez et al. [4], both objective and subjective analyses of the soundscape were conducted, which involved measuring sound pressure levels and statistical percentiles in Cordova, Argentina. Another study by Romero et al. [5], focused on analyzing the soundscape of a recreational festivity in Gandia, Spain, by considering psychoacoustic metrics. Additionally, Diaz et al. [6] developed a methodology to characterize the *Tribunal de les Aigües*, an Intangible Cultural Heritage recognized by UNESCO in Valencia. This particular analysis placed emphasis on the energetic aspects of outdoor acoustics, incorporating room acoustic metrics and describing the sound source. The authors aimed to develop an outdoor acoustic model to recreate the auditory environment and synthesize the soundscape of the *Tribunal*.

In 2014, the International Organisation for Standardisation (ISO) introduced the ISO12913 soundscape standard [1], following the recommendations of the COST Soundscape action [7]. The standard defines soundscape as: "the acoustic environment as perceived or experienced and/or understood by a person or set of people in context [1]. This context includes the relationships between people and activities and places, both spatially and temporally. Therefore, the interaction between the different actors in the acoustic environment establishes a dynamic context that is able to influence the soundscape through different mechanisms, such as: auditory sensation, interpretation of auditory sensation, and responses to the acoustic environment. In this way, the soundscape is differentiated from the acoustic environment (defined as the "sound at the receiver generated by all sound sources present and modified by the environment").

In this work, the study focused on the analysis of the acoustic environment based on the determination of psychoacoustic metrics (loudness, sharpness, roughness and fluctuation strength) to evaluate a global metric which combines all of the previous using the Zwicker's psychoacoustic annoyance model [8] and a modified version of this model, by Di et al. [9], has been explored Also, the evaluation of the subjective response based on a survey called the "Swedish protocol for the evaluation of the quality of the soundscape" [10] in the different heritage environments for the different festive and recreational events.

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2. Materials and Methods

In order to record as closely as possible the sound environment in the listener's position, a binaural recording was carried out at every festive event. The microphones were located at the authors' ears. The use of an artificial head in the measurement environments was not really feasible. In all cases, the requirements of ISO/TS 12913-2 were followed, with regard to the sampling frequency, bit depth, windshield, etc.

The microphones (Roland CS-10EM, omnidirectional, electret, full audio band response, sensitivity -40 dB ref. 1 V/Pa at 1 kHz) were connected to an H4nPro recorder, a handy recorder from ZOOM Corporation. An acoustic calibration signal (94 dB at 1 kHz) was recorded on each of the two channels to calibrate the recordings. The full scale (percentage of the calibration signal) depended on the acoustic environment. In some cases, for instance in *mascletàs*, a level more than 140 dBA was reached. As an example, figure X shows a complete record of a *mascletà*, enlarging the calibration signal and noisy moment zones of the event.

2.1. Psychoacoustic metrics analysed

2.1.1. Loudness

Loudness (*N*) represents the subjective perception of sound volume experienced by humans. It offers a quantifiable measure and understanding of the sensation of sound loudness on a linear scale. The unit of measurement for loudness is known as the *son*, derived from the Latin word *sonare*, meaning "to sound." A sine tone with a frequency of 1 kHz and a level of 40 dB defines one *son*.

The loudness scale is characterized by the relationship where a sound perceived as having twice the loudness on the scale is assigned twice the value in sons. In hearing tests, the loudness of both simple tones and complex sounds is determined by comparing their loudness to that of a sine tone at 1 kHz.

The International Organization for Standardization (ISO) provides ISO 532-1 [11], a specification that outlines the method for determining the loudness of stationary signals. This standard serves as a reference for measuring and evaluating loudness in various contexts.

2.1.2. Sharpness

Sharpness (*S*) is a perceptual attribute associated with the presence of high-frequency components in a sound. It quantifies the perceived level of sharpness in a linear fashion and is measured in units known as *acum*, derived from the Latin word *acum* meaning "sharp". When assessing sharpness, human sensation plays a crucial role.

In the context of measuring sharpness, a narrowband noise centered at 1 kHz, with a bandwidth narrower than 150 Hz and a level of 60 dB, is assigned as the reference value of 1 *acum*. The sharpness parameter holds significant importance in the field of psychoacoustics as it influences the degree of dislike towards specific sounds [8]. The standardization for sharpness measurement can be found in [12], which provides established guidelines and procedures for evaluating this attribute.

2.1.3. Roughness

The roughness parameter (*R*) holds significance in subjectively evaluating sound experiences and guiding sound design processes. It pertains to the perceptibility and qualities of noise emissions. Higher levels of roughness are associated with more noticeable and often perceived as aggressive and annoying sounds, regardless of factors such as loudness or sound pressure level when using the A-weighting filter. The fundamental unit of measurement for roughness is the *asper*, derived from the Latin term *asper*, meaning "harsh".

The sensation of roughness arises when there are time-varying envelopes within a critical frequency range. For example, tones with fluctuations in amplitude or frequency can evoke a sense of

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roughness. At very slow rates (below 10 Hz), these variations are perceived as pulsations or beats. As the frequency of variation increases, different sound impressions emerge, including "R-roughness" (around 20 Hz), which affects the perception of roughness without pinpointing specific temporal changes. Envelope variations between 20 and 300 Hz are typically perceived as roughness. Beyond these frequencies, the primary spectral line and sidebands of pure amplitude-modulated tones become discernible as individual tones.

The perception of roughness is influenced by various factors, including the center frequency, modulation frequency, and modulation depth. The signal level has minimal impact on the overall roughness impression. Understanding and manipulating these parameters can help shape desired roughness characteristics in sound design and evaluation processes.

Increasing the modulation depth strengthens the roughness impression. The dependence on modulation frequency exhibits a bandpass characteristic, where the roughness impression diminishes significantly at very high or very low frequencies. The roughness impression reaches its peak around a modulation frequency of approximately 70 Hz [8].

2.1.4. Tonality and Fluctuation Strength

Tonality (T) refers to the presence of tonal elements or broadband noise in a sound and characterizes the contribution of tones to the overall perception of tonality. The impact of tones varies depending on their frequency, with the highest sensation of tonality typically occurring around 700 Hz. Narrowband noise with a bandwidth narrower than 1 Bark can also be perceived as tonal, albeit to a lesser extent as the bandwidth increases.

The quantification of tonality utilizes the unit of measurement called the "tonality unit" (*tu*). This unit is established based on a 1 kHz sine tone with a level of 60 dB, providing a reference for evaluating and comparing the tonal characteristics of different sounds [8].

Fluctuation strength (F) refers to the perceptual impression caused by variations in signals at extremely low modulation frequencies. The maximum sensation of fluctuation strength is typically observed at modulation frequencies around 4 Hz. The unit of measurement for fluctuation strength is the "vacil" (derived from the Latin word *vacillare*, meaning "to fluctuate"). Similar to roughness, the vacil unit is based on a sinusoidal tone; however, the modulation frequency is set at 4 Hz instead of 70 Hz [8]. The vacil unit serves as a reference for quantifying and comparing the perceived fluctuation strength of different sounds.

2.1.5. Soundscape evaluation using psychoacoustic annoyance as a global metric

The traditional Zwicker's model incorporates the contribution of S when it exceeds 1.75 *acums*. Equations (1) outline the calculation of psychoacoustic annoyance based on this model. If equation (1b) yields an S value below 1.75 *acums*, w_S is considered null. Additionally, for N, the model considers the contribution of the 5^{th} percentile (N_5), which represents the value of N below which the 95^{th} percentile of loudness observations is located, obtained by sorting the data from lowest to highest.

$$\mathrm{PA} = N_5 \cdot (1 + \sqrt{w_S^2 + w_F^2}) \tag{1a}$$

where

$$w_S = \frac{(S - 1.75)}{4} \cdot \log(N_5 + 10) \tag{1b}$$

$$w_F = \frac{2.18}{N_5^{0.4}} \cdot (0.4F + 0.6R) \tag{1c}$$

In the modified version of Zwicker's model, as presented in [9], an additional term is introduced in equation (1a) to consider the tonal aspect of the analyzed sounds. This term is represented in equation (2a), where the variable w_T in equation (2b) incorporates the influence of tonality (T). The extraction of this tonal component is achieved using the Aures tonality model [13], which employs Terhardt's algorithm [14] to extract the pitch of complex tonal signals.

$$\mathrm{PA} = N_5 \cdot (1 + \sqrt{w_S^2 + w_F^2 + w_T^2}) \tag{2a}$$

where

$$w_T = \frac{6.41}{N_5^{0.52}} \cdot T \tag{2b}$$

Subsequently, assessing any of these metrics enables a means to compare the perception of the soundscape among individuals involved. Although the term "annoyance" may carry a negative connotation, it serves as a way to quantify this particular perception. Additionally, Zwicker's theory encompasses the concept of "pleasantness," which can also be evaluated and taken into consideration.

2.2. Subjective assessment of soundscape

The evaluation and description of the soundscape in a given situation, considering factors like acoustics, environment, context, and personal elements, is defined in ISO 12913-1 [1]. This standard provides a definition and conceptual framework for the soundscape, which refers to the auditory environment that individuals or groups perceive, experience, and understand within a specific context. Hence, people may have varying responses to a particular acoustic environment due to their personal backgrounds, socio-cultural influences, and past experiences. In order to ensure consistent evaluations of soundscapes, it is crucial to follow standardized testing procedures. Numerous studies conducted in different countries have explored how various factors influence the outcomes of these evaluations [15–18]. Building on this research, Axelsson et al. [19,20] developed the Swedish soundscape quality protocol. This protocol employs eight adjectives (Annoying, Calm, Chaotic, Eventful, Exciting, Monotonous, Pleasant, and Uneventful) to assess the perceived emotional quality using a Likert scale ranging from 1 to 5, where 1 represents "strongly disagree" and 5 signifies "strongly agree." Additionally, the protocol may also request information regarding certain social aspects such as gender and age.

The scientific community predominantly employs the Swedish soundscape quality protocol, which has been translated into 15 languages. In this study, we have employed this protocol to evaluate the festive events presented in this research. To simplify data collection from participants, we have developed a web application using Google Forms as a platform for implementing this assessment tool. Each festivity is accompanied by audio clips ranging from 4 to 6 minutes, capturing distinct moments and featuring a brief explanation and a video of the event. The evaluation process aligns with the guidelines provided in the ISO 12913-3 standard [3], which outlines the calculation of the Mean Opinion Score (MOS) for each event in the form of a "rating rose" [3]. Furthermore, additional statistical analyses are conducted on these responses.

3. Results

3.1. Soundscape evaluation in terms of psycho-acoustic metrics

The assessment of various soundscapes using psycho-acoustic metrics was conducted utilizing two different software tools. The first software, ArtemiS Suite[1], is a modular software developed by HeadAcoustics. Specifically, we utilized the psycho-acoustic module [21] within ArtemiS Suite to calculate metrics such as loudness vs. time, sharpness vs. time, fluctuation strength vs. time, roughness vs. time, and tonality.

[1] https://www.head-acoustics.com/products/analysis-software/artemis-suite (Accessed on 04/05/2023)

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For the second software, URPAA[2], we modified the configuration to compute all the aforementioned metrics on a per-second basis.

3.1.1. Sound walks description in the festive events

The comparison of psycho-acoustic annoyance using Zwicker's expression (equation 1a) and a modified version incorporating tonality (equation 2a), along with a comparison of results from URPAA and ArtemiS software, is illustrated in Figures 1, 2, and 3. The figures demonstrate that the general patterns across different sound walks and software tools are consistent. However, discrepancies arise during specific time periods due to variations in the resolutions employed by each software.

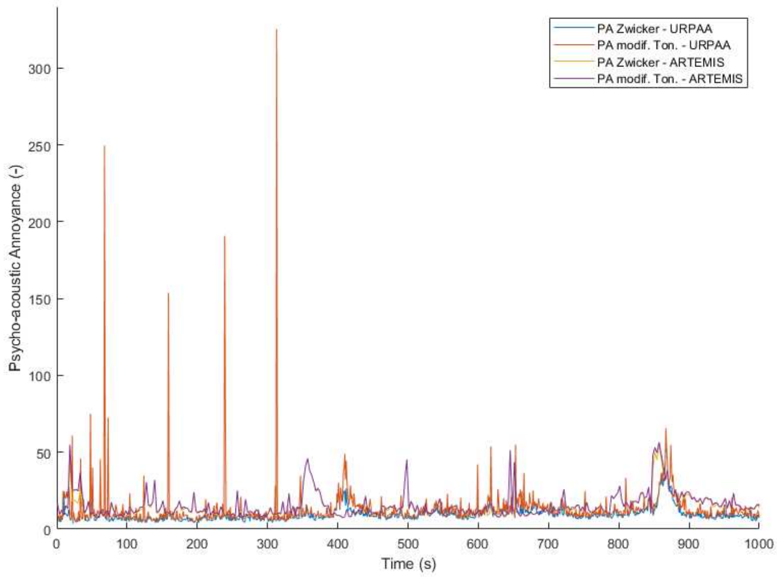

Figure 1. Graphic of psycho-acoustic annoyance in Fallas' "ofrena" to the Holy Virgin on March 17th.

2 https://github.com/jausegar/urbauramon/tree/master/URPAA (Accessed on 04/05/2023)

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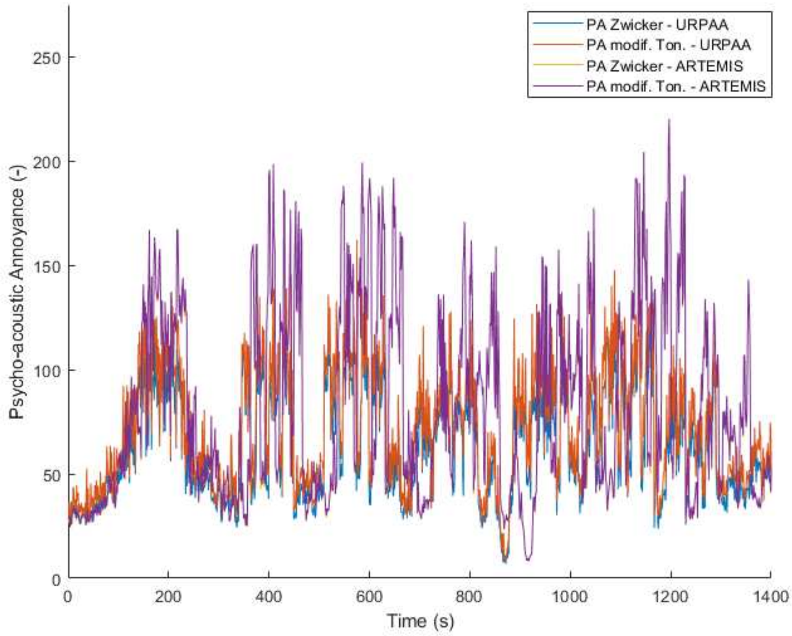

Figure 2. Graphic of psycho-acoustic annoyance in the Festivity of the "Mare de Déu de la Salut" in Algemesi on September 7th.

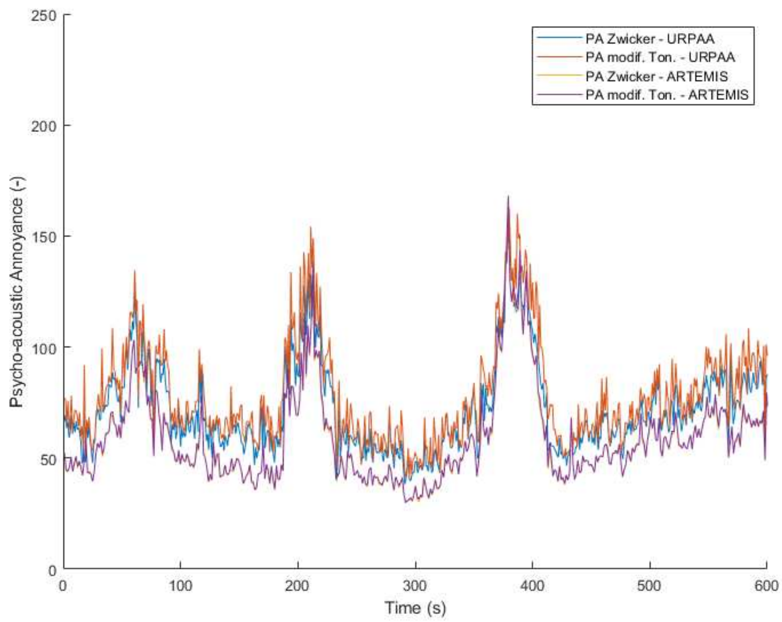

Figure 3. Graphic of psycho-acoustic annoyance in the Festivity of "Moros y Cristianos" in Villena on September 6th.

The comparison of various soundscapes is depicted in Figure 4. The figure reveals that the soundscapes during the festivities of Algemesi and Villena exhibit some similarities, while in the Falla's "ofrena," the sound sources are more dispersed temporarily, resulting in a subjective perception of a relatively more "chaotic" environment, despite the lower average value for psycho-acoustic annoyance (PA) in this case.

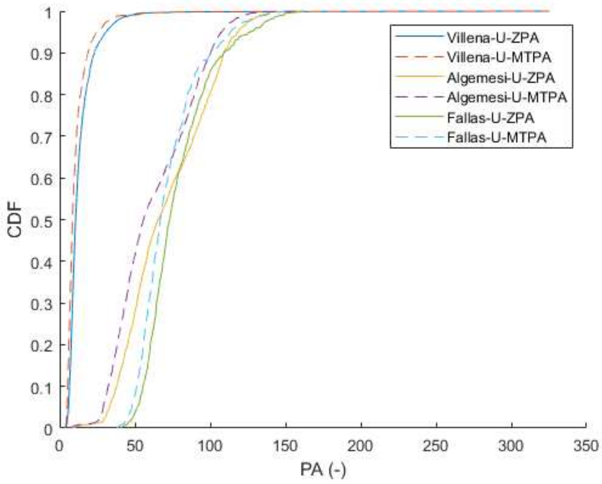

Figure 4. Graphic comparing the different Cumulative Density Functions of psycho-acoustic annoyance with URPAA software considering Zwicker's PA model (continuous line) and modified PA model (dashed line).

3.1.2. Fireworks soundscape description

Also, in the festivities of Sanfermines in Pamplona and Fallas in Valencia, we have described another type of soundscape, the fireworks. This kind of soundscape is not so "friendly" or pleasant for everybody.

Usually, a fireworks show is a symphony of explosive brilliance that captivates the senses with its resounding sound characteristics. As the first fiery burst illuminates the sky, there is an initial crackling and sizzling sound, reminiscent of a magical spark igniting the air. The sharp hiss is soon followed by a series of powerful booms that reverberate through the atmosphere, echoing with intensity. These explosions create a percussive chorus, each explosion distinct in its tone and resonance. The larger fireworks command attention with deep, thunderous roars that rumble in the chest, while smaller bursts contribute with high-pitched pops and crackles that add a touch of whimsy to the symphony. Together, these explosive crescendos and delicate crackles compose an auditory masterpiece, enhancing the visual spectacle and leaving an indelible impression of awe and wonder.

In Figure 5, we can see two cases of fireworks displays at Fallas in Valencia. In it, we observe that the PA describes well the evolution of loudness/sharpness. However, the tonal components are not so well appreciated, as the modified Zwicker's model with tonality is very similar to the Zwicker's PA model. In this case, the final *crescendo* is really perceptible. The maximum sound pressure level in these cases is around 125 dBA. Finally, we observe some kind of structure in these shows that could be a matter for new studies.

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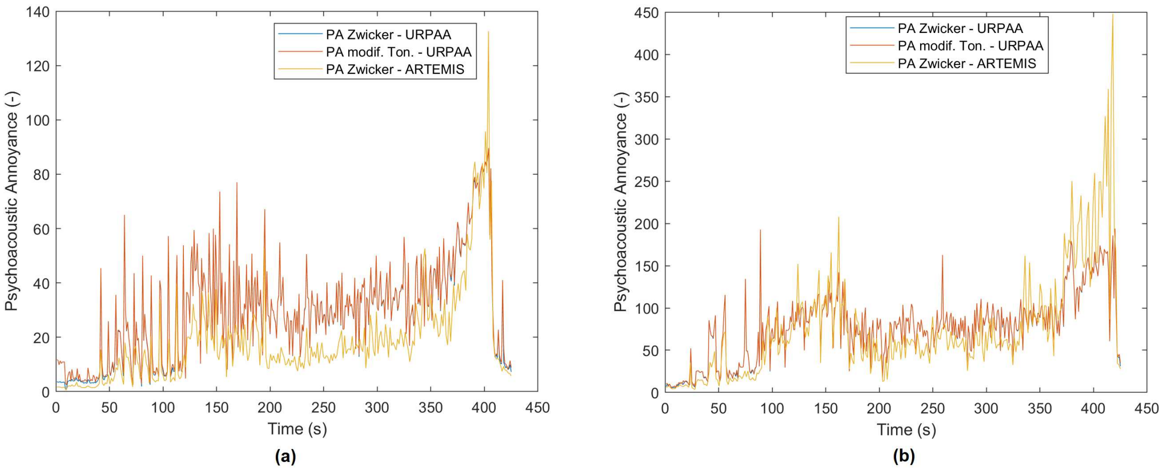

Figure 5. Graphic of psycho-acoustic annoyance in Fallas fireworks on March 18th and 19th.

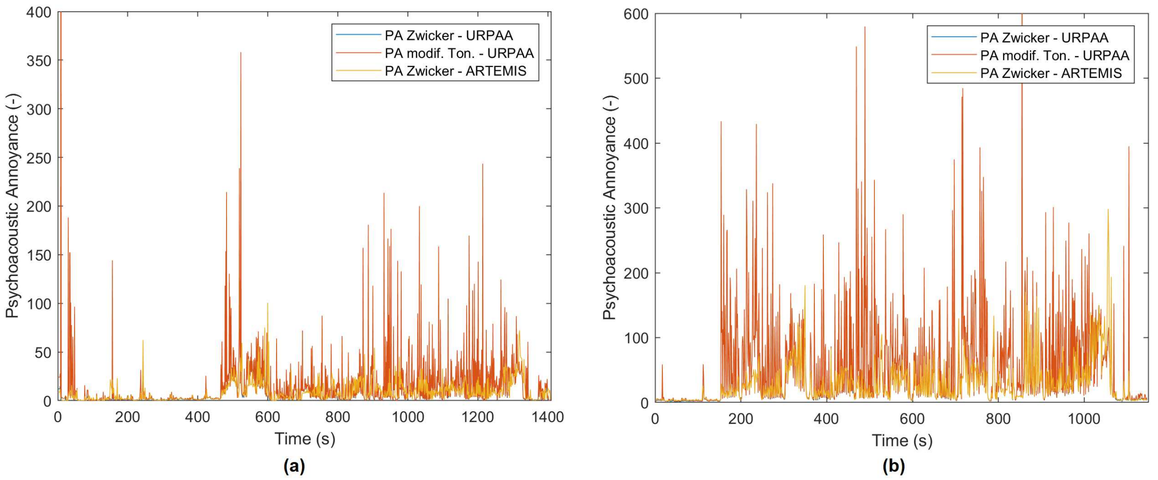

Figure 6. Graphic of psycho-acoustic annoyance in Sanfermines fireworks on July 9th and 10th.

Figure 6 shows two fireworks castles at Sanfermines in Pamplona. In these cases, the observer is closer to the event. Here, the structure is not so well defined, as in the previous case, but the use of PA as a global metric to describe the evolution in the soundscape is helpful. Perhaps a moving average could help to see a structural scheme in this case.

Figure 7 shows the cumulative distribution functions of Zwicker's PA model for each event with the two pieces of software (URPAA and ArtemiS).

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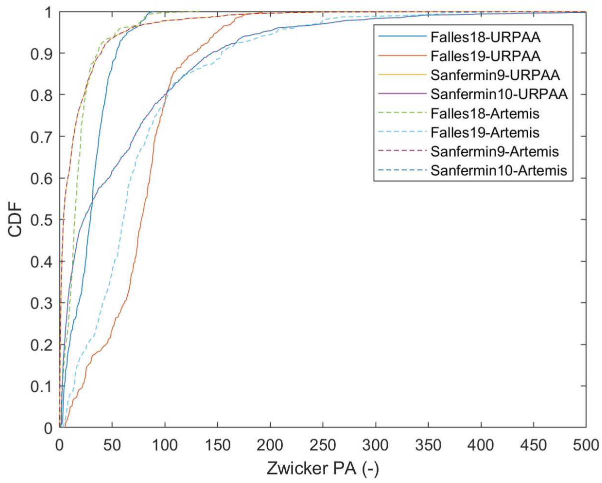

Figure 7. Graphic comparing the different Cumulative Density Function of psycho-acoustic annoyance.

3.2. Subjective response assessment

From the survey provided, the values can be related to the subjective response evaluated with the public survey based on the Swedish Soundscape Quality Protocol. We obtained 48 participants with an average age of 59.2 years.

3.2.1. Sound walks survey evaluation

Table 1 shows the statistical values of the subjective ratings (on a scale of 1 to 5, where 1 is "strongly disagree" and 5 is "strongly agree") for each of the respondents' perceived soundscape ratings, also considering the 95% confidence interval (CI) and the p-value in the sound walks subjective evaluation.

In Figure 8, it is shown that in general, the soundscape in Villena and Algemesi festivities are perceived on average as quite similar, although the second one is perceived as calmer (2.6/1.9) and less annoying (2.1/1.8) than the first one, but this first soundscape (in Villena) is perceived as more uneventful (2.6/2.1) than the first one. The Falla's "ofrena" soundscape is perceived as somehow different, as it is more chaotic (3.4), less vibrant (3.1) and less pleasant (3.6) than the others.

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Table 1. Statistical values for the surveys within the different sound walks.

		N	Mean	Std.Dev.	95% CI Lower L	Upper L	p-value
Pleasant	FMD Algemesi	48	3.9	0.9	3.6	4.2	0.021
	FMC Villena	48	4.1	0.8	3.8	4.3	
	Fallas Ofrena	48	3.6	0.9	3.3	3.8	
Chaotic	FMD Algemesi	48	2.6	1.1	2.3	2.9	<0.001
	FMC Villena	48	2.3	1.4	1.9	2.7	
	Fallas Ofrena	48	3.4	1.4	1.9	2.7	
Vibrant	FMD Algemesi	48	3.6	0.7	3.4	3.8	0.027
	FMC Villena	48	3.4	1.1	3.1	3.7	
	Fallas Ofrena	47	3.1	1.1	2.8	3.4	
Uneventful	FMD Algemesi	48	2.1	1.1	1.8	2.4	0.033
	FMC Villena	48	2.6	1.1	2.3	2.9	
	Fallas Ofrena	48	2.6	1.1	2.3	2.9	
Calm	FMD Algemesi	48	1.9	1.3	1.5	2.2	0.007
	FMC Villena	48	2.6	0.9	2.3	2.8	
	Fallas Ofrena	48	2.5	1.2	2.1	2.9	
Annoying	FMD Algemesi	47	1.8	1.0	1.5	2.1	0.069
	FMC Villena	48	2.1	1.2	1.8	2.5	
	Fallas Ofrena	48	2.3	1.1	2.0	2.6	
Eventful	FMD Algemesi	47	3.5	1.3	3.1	3.9	0.981
	FMC Villena	48	3.5	1.3	3.2	3.8	
	Fallas Ofrena	47	3.5	1.0	3.2	3.8	
Monotonous	FMD Algemesi	47	2.4	1.2	2.0	2.7	0.987
	FMC Villena	48	2.4	1.3	2.0	2.7	
	Fallas Ofrena	45	2.3	1.3	1.9	2.7	

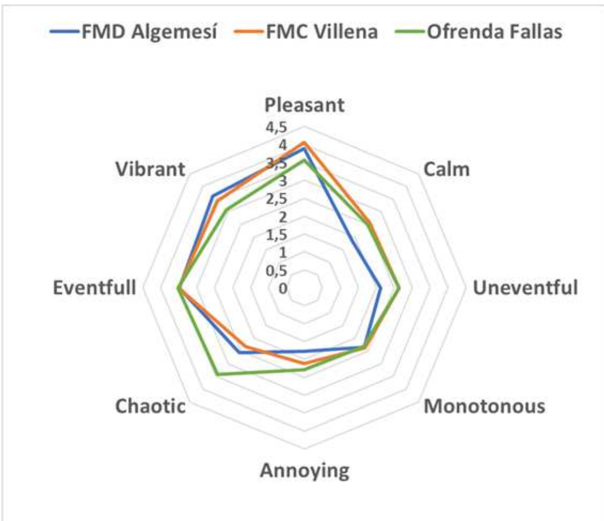

Figure 8. Rating rose diagram with mean values for the different sound-walks.

3.2.2. Fireworks displays survey evaluation

Table 2 shows the statistical values of the subjective ratings (on a scale of 1 to 5, where 1 is “strongly disagree” and 5 is “strongly agree”) for each of the respondents’ perceived soundscape

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ratings, also considering the 95% confidence interval (CI) and the p-value in the firework displays subjective evaluation.

Table 2. Statistical values for the surveys within the different fireworks displays.

		N	Mean	Std.Dev.	p-value
Pleasant	Mascletá	48	2.9	1.3	0.003
	Sanfermines	44	3.7	1.2	
Calm	Mascletá	48	2.5	1.4	0.165
	Sanfermines	44	2.2	1.1	
With few active events	Mascletá	48	3.1	1.1	0.026
	Sanfermines	44	2.5	1.3	
Monotonous	Mascletá	48	2.8	1.5	0.960
	Sanfermines	40	2.8	1.6	
Annoying	Mascletá	48	2.7	1.4	0.169
	Sanfermines	44	2.3	1.2	
Chaotic	Mascletá	47	2.7	1.2	0.329
	Sanfermines	44	2.5	1.2	
Exciting	Mascletá	48	3.2	1.3	0.009
	Sanfermines	44	2.5	1.2	
Vibrant	Mascletá	48	3.2	1.4	<0.001
	Sanfermines	44	4.0	1.1	

Figure 9 shows the overall averages of the subjective ratings (on a scale of 1 to 5, where 1 is "strongly disagree" and 5 is "strongly agree") for each of the respondents' perceived soundscape ratings. In this figure, it is shown that in general, Fallas' mascleta (2.7/1.4) soundscape is perceived as more annoying/unpleasant than Sanfermin fireworks (2.3/1.2), although listeners perceive Falla's mascleta soundscape (2.7/1.2) a little bit more chaotic than Sanfermin (2.5/1.2). Surprisingly, Sanfermin firework (4.0/1.1) is perceived as more vibrant (3.0/1.1) than the mascletá, although both soundscapes are perceived as monotonous with the same mean value.

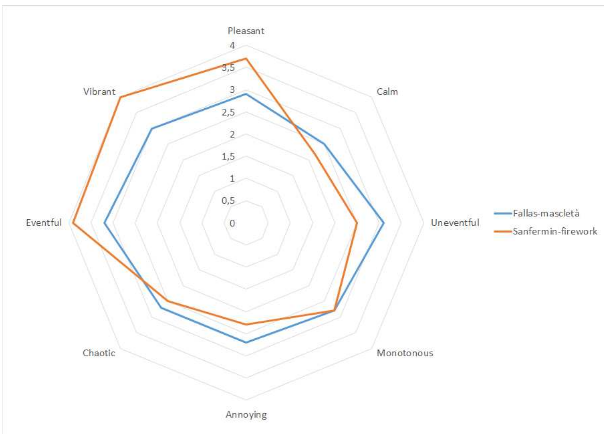

Figure 9. Rating rose diagram with mean values for the different fireworks displays.

4. Conclusions

In this work, we have described the soundscape in different festivities in Spain: "Mare de Deu de la Salut" in Algemesi, "Moros y Cristianos" in Villena, Sanfermines in Pamplona and Fallas in Valencia.

This description has been made in terms of psycho-acoustic metrics (N, S, F, R and T) and Zwicker's psychoacoustic annoyance (PA) model and a modified version of this one. The cumulative distribution of this global metric (PA) has been used to grade each one of the sound walks and fireworks displays.

Also, an application of the "Swedish protocol", collected in ISO 12913-3, has been done. The results have shown that the soundscape in Villena and Algemesi festivities are perceived on average as quite similar, but in Algemesi, it is perceived as calmer and less annoying than in Villena, but the soundscape of the festivity in Villena is perceived as more uneventful than in Algemesi. In the Falla's "ofrena", the soundscape is perceived as more chaotic, less vibrant and less pleasant than in the other cases.

In the case of fireworks display soundscapes, the sound events analyzed are obviously of very high noise levels, especially the mascletá. This is largely due to the close proximity between the explosion of the fireworks and people as well as to a more closed environment, with added reverberation. The psychoacoustic annoyance (PA) values are extremely high. However, the people coming to listen to these events do not manifest a sense of annoyance. In fact, the louder they are, the longer and more intense are the round of vigorous applause with which the audience thanks the show. The explanation seems clear; we are analyzing sound sensations (psychoacoustics) and not only sound levels. One issue that slightly surprised us is that we expected a higher rating of 'vibrant' in the case of the mascletá. We suspect that listening "in situ" would modify significantly the sensation, compared to simply listening to a recording. The atmosphere during a mascletá is truly exciting and unique.

For future work, it is intended to extend this study to a larger number of festivities to describe other soundscapes for classification purposes and to have a larger dataset of fireworks displays in order to evaluate their structure and develop some specific metric to assess the firework quality.

Author Contributions: Conceptualization, A.G.P and J.S.G.; methodology, R.C. and M.A.; software, J.S.G., S.C.J; validation, M.A., J.S.G. and R.C.; formal analysis, R.C.; investigation, X.X.; resources, J.S.G, A.G.P. and M.A.; data curation, S.C.J. and R.C; writing—original draft preparation, J.S.G.; writing—review and editing, R.C., M.A., A.G.P and S.C.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Spanish Ministry of Economy and Innovation grant number BIA2016-76957-C3.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: In this section you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflict of interest.

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