AN INVESTIGATION INTO THE PERCEPTION OF SPATIAL TECHNIQUES USED IN MULTI-CHANNEL ELECTROACOUSTIC MUSIC

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ABSTRACT

The paper reports on an experiment designed to examine the perception of the spatial attributes of envelopment and engulfment in spatial techniques used in multi-channel electroacoustic music. Four spatial techniques were examined, they were: (i) Timbre Spatialisation [1], (ii) Spectral Splitting [2], (iii) Amplitude Point Source [3], and the proposed (iv) Dynamic Spectral Spatialisation technique. The multi-channel loudspeaker configuration consisted of 16 loudspeakers, eight horizontal and eight elevated. The experiment was design whereby the four above mentioned spatial techniques were presented in three conditions: (i) Horizontal only, (ii) Elevated only, and (iii) Horizontal and Elevated, referred to as Three Dimensional (3D), loudspeaker configurations. The experiment took place in the Spatialisation Auditory Display Environment (SpADE) at the University of Limerick and has physical attributes that conform to the ITU-R BS.1116-1 listening room standard [4]. Each participant individually undertook a listening experiment whereby they were asked to evaluate each spatial technique presented in the three conditions for perceived levels of envelopment and engulfment. A factorial analysis of variance (ANOVA) was performed on the envelopment and engulfment ratings. The results of the analysis revealed a significant main effect for spatial techniques and loudspeaker configurations for both spatial attributes. Participants rated the Dynamic Spectral Spatialisation technique highest for levels of envelopment and engulfment. The Horizontal loudspeaker configuration was rated highest for envelopment and the Elevated loudspeaker configuration was rated highest for engulfment.

1. Introduction

Composers have engaged in multi-channel sound spatialisation since the early 1950's. Some of the first performances of electroacoustic works used distributed loudspeakers to spatialise sound [5]. A strong association between electroacoustic music and sound spatialisation has developed since. This association has not diminished with recent research findings revealing that composers increasingly prefer to use multi-channel (5.1, quadraphonic and eight channel) to traditional stereo loudspeakers for composing and performance of works [6]. It was also found that there is an increase in the use of different sound spatialisation techniques by composers. What techniques do composer use to spatial sound?

Previous research undertaken by the author reveals that composers have developed many sound spatialisation techniques, which can be identified from one of three categories: granular, spectral or panning techniques [7]. A cross-section of techniques from these categories where chosen to be examined in this perceptual study. It has been argued that in order for sound spatialisation techniques to be effective they must be perceived by listeners [8]. But what do composers or intend for listeners to perceive when experiencing multi-channel sound? Again previous research undertaken by the author [9] suggests that established composers commonly use terms such as 'envelopment', 'immersiveness' or "surroundness" to describe their perceptual experience of multi-channel sound. Kendall [10], points out that there are no commonly understood terms to describe specific aspects of multi-channel space in electroacoustic music. In this study spatial attributes from related disciplines with similar meanings to the terms stated by established composers are used to examine spatial technique. This investigation takes the form of a perceptual listening experiment with listener participants.

2. Experiment Design

2.1 Spatial attributes

Spatial attributes have been discussed extensively within perceptual research of concert hall acoustics and reproduced audio research [i.e. 11, 12, 13]. Attributes are easily definable terms that can be validated through physical measures and their ratings predicted by listeners. As mentioned above a sense of 'envelopment' and 'immersiveness' are phrases used by composers when perceiving multi-channel electroacoustic music [7]. The spatial attributes that are most similar in definition to these phrases are envelopment and engulfment. 'Listener envelopment' (LEV) in the traditional sense is caused by late reverberant sound from the side resulting in a feeling of 'immersion' [16]. Rumsey [17], states that within multi-channel reproduced audio, envelopment is perceived by listeners from a number of dry and direct sound sources and not as a result of late reflected sound. Rumsey defines this type of envelopment as 'ensemble' envelopment [17]. Within this study listeners are surrounded by sources that may not contain late reflected sound, therefore we refer to envelopment in the sense of 'ensemble' envelopment.

It is argued that the use of elevated loudspeakers is best evaluated using the spatial term engulfment [18, 19]. Engulfment is defined as the sense of being 'covered' in sound as opposed to being simply 'surrounded' as defined by the term envelopment. Perceptual studies have found that engulfment and envelopment are perceived as two individual spatial attributes [18, 19]. Listeners perceive engulfment as perceptually different to envelopment when evaluating multi-channel sound with elevated loudspeakers [18]. It is believed that engulfment is unique to elevated sound and not possible with horizontally configured loudspeakers (18). Within this study engulfment will be used to describe the sense of being 'covered in sound'.

The terms envelopment and engulfment are deemed appropriate descriptive terms for evaluating multi-channel electroacoustic music. Therefore, throughout this study the following dependent variables presented as rating scales are: (1) envelopment and (2) engulfment.

2.2 Complex stimuli

To date the majority of stimuli used in perceptual experiments of reproduced audio have consisted of concert music (i.e. 20, 21, 22, 23) or soundscapes (24). Others have used complex stimuli in the form of composed electroacoustic music [18, 19, 25]. According to Bech and Zacharov [26], the main objective of the stimuli in a perceptual experiment is to excite the perceptual difference between the variables under evaluation. As long as the stimuli excites the chosen response attributes, no limitations are placed on what the signal should be. Bech and Zacharov [26] further state that the category of signal is important to the general validity of a study and should be relevant to the system being evaluated. According to Rumsey [13], when asking subjects to evaluate attributes, the sonic complexity of the source material being evaluated should not be so varying or complex. If it is too complex, multiple factors or attributes not intended for experiment evaluation may be included. In order to minimize the effect of assessing unintended factors, it is recommended that a sound source, which is relatively static in character be used.

Taking these points into consideration, the stimuli deemed relevant for this experiment is complex sound in the form of composed electroacoustic music. The characteristics of the composed music will be that of a long sustained sound source with limited variation in dynamic range.

2.3 Stimuli creation and sonic complexity

The sound material chosen was an excerpt from Claude Debussy *Prélude à l'après-midi d'un faune* (1894). This excerpt was chosen because of its rich harmonic content. DSP techniques were applied to the excerpt in order to calibrate the stimuli and to simulate sonic characteristics commonly heard in electroacoustic music. The DSP processes applied were time–stretching and transposition. The excerpt was first time-stretched by a multiple of six and then transposed five times. The transposition process involved transposing the original excerpt upwards or downward by octaves to accommodate one of five frequency bands. The frequency ranges of the five bands were: Low (L), 20Hz-250 Hz; Low-Mid (LM), 250Hz-2kHz; MID (M), 2kHz-4kHz; High (H), 4kHz-8kHz; and Ultra-High (UH), 8kHz and higher. Each excerpt was 15 seconds in length, had a 100ms onset and offset applied, and had the same amplitude envelope. In order to remove any perceived loudness difference between each frequency band, each was individually calibrated to read 68dB SPL (+/- 0.1dB) C weighting with Slow response from the centre sweet spot using the Acoustilyzer AL1 SPL meter. This standardization eliminated participants possible bias towards one spatial scene over another based on perceived loudness. The levels were adjusted via the output bus within Logic Pro 9 resulting in each band having the same loudness. The five frequency bands were then combined together to create one sonic layer, which was used as the stimuli for the study. All created frequency bands and the final sonic layer were exported as a 24bit/44.1kHz AIFF files.

2.4 Experimental loudspeaker configuration

Three loudspeakers configurations were used in this experiment: a horizontal, an elevated and a 3D configuration. A 3D audio configuration is defined as one that renders sounds using both elevated and horizontal loudspeakers [27]. All three configurations were constructed within one loudspeaker setup at the Spatialisation and Auditory Display Environment (SpADE) located at the Digital Media & Arts Research Centre (DMARC), University of Limerick. The horizontal set-up consisted of eight loudspeakers positioned equidistantly in a circular manner with a radius of 1.71m around a centre sweet spot. The loudspeakers were positioned at 0º, 45º, 90º, 135º, 180º, 225º, 270º, and 315º in relation to the centre sweet spot position at a height of 1.20cm from the floor.

The elevated set-up consisted of eight loudspeakers positioned equidistantly in a circular manner with a distance of 241.8cm from the centre sweet spot. The loudspeakers were located at a height of 291cm with 45º angle of elevation and at 0º, 45º, 90º, 135º, 225º, 270º, and 315º position from the centre sweet spot. The elevated loudspeakers were positioned downward and facing the listening position at a 45º angles. Figure 1. shows the elevated and horizontal loudspeaker configurations. Figure 2. shows the angular and distance relationship between the elevated and horizontal loudspeakers.

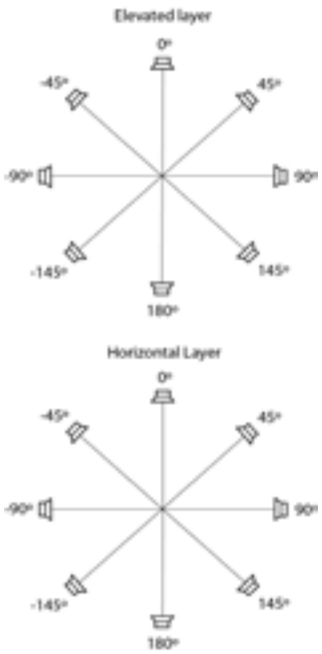

Figure 1. The elevated and horizontal loudspeaker configurations used in the current study. The illustration shows the angular position in degrees for each configuration.

When spatial scenes were presented within the 3D set-up a delay was applied to all horizontal loudspeakers to compensate for the different in distance between centre sweet spot and horizontal and elevated loudspeakers. A 2.08ms or 92 samples at 44.1kHz delay was applied equally to all horizontal loudspeakers within this configuration. This was achieved using a delay plug-in in Logic Pro 9.

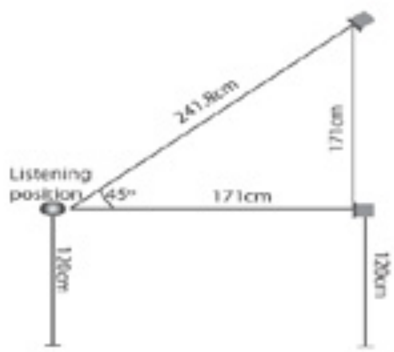

Figure 2. The angular and distance relationship between elevated and horizontal loudspeakers [22].

2.5 Listening room environment

Given that there is no listening room standard for 3D multi-channel reproduction, the ITU-R BS.1116-1 standard is used for this perceptual study. This standard is recommended for 5- and 7- multi-channel reproductions but has also been adopted for listening rooms incorporating 3-D multi-channel configurations [e.g. 27]. This listening room standard or ones similar have been utilized in many perceptual studies where spatial quality is evaluated [i.e. 15, 17, 20, 23, 24]. SpADE's dimensions, volume and resultant reverberation time were within the defined ranges of the above-mentioned standard.

2.6 Spatial techniques - Independent variables

The spatial techniques evaluated within this study are (i) Timbre Spatialisation [1], (ii) Spectral Splitting [2], (iii) Amplitude Point Source [3], and the proposed (iv) Dynamic Spectral Spatialisation technique. Two additional spatial techniques, Static Timbre Spatialisation [1] and Full Band Decorrelation [28] were used in the participant training session. These techniques were chosen from a cross section of granular, spectral and panning techniques previously complied [7].

2.6.1 Dynamic Spectral Spatialisation

The dynamic spectral spatialisation technique is based on Potard's sub-band decorrelation technique [29]. The author added an additional dynamic spectral parameter. Potard's sub-band decorrelation technique involves splitting a signal up into different frequency bands and applying different amounts of decorrelation to each band [29]. This provides the ability to control the amount of decorrelation applied to each frequency band. For example, low frequency content is uncorrelated and high frequency content is left correlated. A time varying or non-time varying decorrelation technique can be applied. Each decorrelated frequency 'sub-band' is outputted to a point source within a multi-channel configuration. This results in the sound source being perceived as having different spatial positions. This effect is called the spatial Fourier decomposition effect [29].

Potard's technique is implemented within this study by firstly splitting the input into different frequency bands using four band-pass filters. The bandwidth ranges of the four filters were: Low, 20Hz-250 Hz; Low-Mid, 250Hz-2kHz; Mid, 2kHz-4kHz; High, 4kHz-20kHz. The author added a time-varying spectral parameter. This parameter involved changing the band-pass filters from static to dynamic. Using a filter sweeping method, each filtered band gradually moves from lower to higher frequency range and vice-versa over time. For example the Low (L) range band sweeps to High, the High to Low, the Mid to Mid-high and the Mid-High to Mid.

As outlined by Potard [29], each sub-band signal is than decorrelated using Kendal's [30] static or dynamic full band decorrelation techniques. Full band decorrelation is implemented by combining a delayed sub-band signal with a duplicate non-delayed sub-band signal. The amount of delay applied is 20 ms. This combination of delayed and non-delayed signals creates a number of decorrelated signals. A cross fader module is used to control the amount of correlation. This is achieved by injecting an additional non-delayed sub-band signal into these decorrelated signals.

This same process is used to implement dynamic full band decorrelation but with an additional time-varying parameter. The amount of delay applied to the sub-band signal varies over time. The delay amount varies from 10 ms to 30 ms over the duration of a spatial scene. A higher number of un-correlated signals can be created using a dynamic full band decorrelation over static full band decorrelation [29].

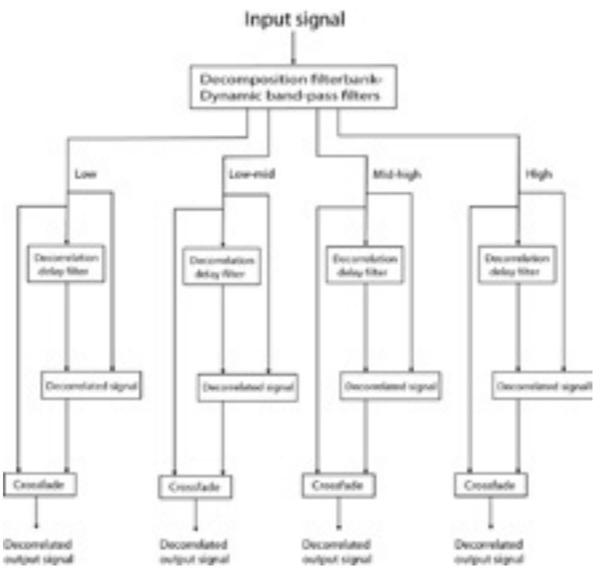

Figure 3. Diagram of the dynamic decorrelation technique

3. Perceptual experiment

This section reports on the procedure and results of the perceptual experiment. The experiment is designed to examine the perception of the spatial attributes of envelopment and engulfment in spatial techniques used in multi-channel electroacoustic music. A factorial analysis of variance (ANOVA) is performed on listener participant's envelopment and engulfment ratings of spatial techniques and loudspeaker configurations. Results report on the main effects of the two independent variables: four spatial techniques and three loudspeaker configurations).

3.1 Participants

A total of 24 participants took part in the listening experiment. The participants were made up of 12 undergraduate and 12 postgraduate students studying Bachelor of Science in Music, Media and Performance Technology and Master of Science in Music Technology programs at DMARC, University of Limerick. This was made up of 17 male and eight female with a mean age of 26.3 years old ranging between 19 and 43 years of age (SD = 7.74 yrs). All participants reported that they had normal hearing ability with five reporting to have undertaken a listening test in the past. The participants have been engaged in music or sound studies, for between one and 20 years with a mean of seven years (SD = 5.08 yrs).

All participants were deemed to be either experienced or expert listeners. Seventeen participants reported that they were composers of music, with a mean of seven years ranging between one and 20 years (SD = 5.08 yrs). Out of the 17 composers, nine reported that they had engaged in multi-channel composition and no participants reporting they had composed music for a three-dimensional loudspeaker configurations. Furthermore, 13 participants stated that they listen to electroacoustic music and seven reported that they had attended a live concert performance of electroacoustic music. All participants received course credit in exchange for taking part in the listening experiment.

3.2 Spatial scenes

Spatial scenes in this study will refer to as composed audio scenes that are reproduced using loudspeakers and perceptually evaluated by participants for their 3D characteristic [17]. Spatial audio scenes also refer to composed audio spatialised using the four techniques; Timbre Spatialisation [1], Spectral Splitting [2], Amplitude Point Source Panning [3], and Dynamic Spectral Spatialisation presented within three multichannel loudspeaker configurations; Horizontal, Elevated and 3D. The amplitude levels of all spatial audio scenes spatialised with each technique were calibrated within horizontal only, elevated only and 3D only loudspeaker configurations to read a maximum of 68 dB SPL (+/- 0.1dB) at C weighting with slow response. The calibration was undertaken using the SPL meter from the centre listening position. This standardization eliminated participants possible bias towards one spatial scene over another based on perceived loudness.

3.3 Spatial diffusion

According to Cheng [31] composers commonly use sound diffusion in multi-channel electroacoustic music. Sound diffusion refers to the practice of localising and moving sound throughout a space using multiple loudspeakers. This can be achieved by controlling the amplitude levels, equalization and placement of sound sources [31].

A sound diffusion process was applied to all horizontal, elevated and 3D spatial scenes. An amplitude point source panning technique was used to create a sound diffusion [3]. This involved adjusting the amplitude levels of individual loudspeakers so that sound sources are perceived as originating from specific locations or moving within the listening space.

Figure 4. Amplitude point source panning [23] was used to create a sound diffusion for each spatial scene. This involved presenting a single sound source from the horizontal front centre loudspeaker. Over the duration of the first five seconds, sound sources were gradually presented from the remaining loudspeakers within a configuration.

In this experiment, the sound diffusion is initially perceived as originating from directly in front of the listening position and then gradually moving to the rest of the listening space. This is achieved by first presenting the sound source on the front centre horizontal loudspeaker (positioned at 0º from the centre listening position) only for each spatial scene. Over the duration of the first five seconds the amplitude levels of the rest of the speakers gradually increased so that at the end of five seconds all loudspeakers reached equal amplitude level. This same process was used for all spatial scenes presented on horizontal, elevated and 3D loudspeaker configurations. The sound diffusion process is illustrated in Figure 4.

3.4 Equipment and calibration

Three different loudspeaker configurations were constructed within one setup. These consisted of an eight-channel horizontal, an eight channel elevated and a 16-channel 3D configuration. The specifications of each configuration are outlined above (see Section 2.4.). All 16 loudspeakers used were identical Genelec 8030a self-powered speakers. An Apple Macintosh Pro computer running Logic Pro 9 presented the experiment. The Macintosh Pro was connected via firewire to an M-Audio Audiophile 192 PCI interface. The 16 analogue outputs of the interface were directed to the 16 loudspeakers used, giving a total of 16 outputs. These outputs were directly connected to the 8030a loudspeakers inputs using 1/4” to XLR connectors. All loudspeakers in the SpADE were calibrated with pink noise from 1 meter at 70dB SPL C weighting with slow response. The levels were adjusted via the output buses in Logic Pro so that each loudspeaker individual read 70 dB SPL (+/- 0.1dB).

3.5 Listening test procedure

The listening experiment was run individually for each participant. The experiment consisted of a training phase and an experiment phase. The training phase consisted of explaining the experiment procedures and providing a definition of each of the spatial attributes to be evaluated. Participants were informed that a series of spatial audio scenes would be presented and that they were to perceptually rate each excerpt for levels of envelopment and engulfment. The following explanation of terms was included in the Information Sheet for the participants:

Envelopment: The sense of being surrounded by sound

Engulfment: The sense of being covered by sound.

A short verbal example of where each attribute could be perceived in a natural environment was also provided. These were as follows; “A sense of envelopment could be perceived when surrounded by a crowd of people” and “a sense of engulfment could be perceived from lightning or fireworks”.

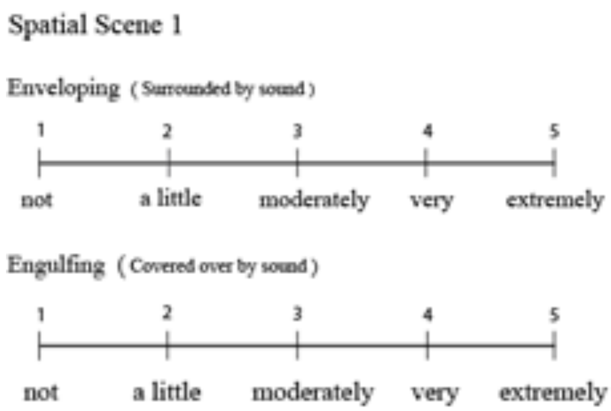

Figure 5. Participants rated each spatial scene for levels of envelopment and engulfment using a 5-level Likert scale. Participants were instructed to mark X anywhere along the scale, not just at the indicated anchor points.

Each participant undertook a short training session prior the listening experiment. Each participant was seated in the designated sweet spot position located in the centre of the loudspeaker set up. Six spatial scenes composed using the two additional spatial techniques not used in the experiment were presented in a short training session. A 5-level Likert scale was used to elicit participant responses (see Figure. 5). The procedure of how to rate spatial scenes using the Likert scale was explained. Participants were asked to mark X at any point along the scales, not just on the indicated anchor points.

This training session was undertaken to familiarize the participant with the format of the listening experiment. Each participant was advised of the possible advantages of head movement (left/right and up/down movement) in perceiving sound and was advised that they could move their heads if they so wished to do so. Participants were asked to rate each scene after it had finished playing. No other information was provided to the participants regarding the aims of the experiment.

The experiment phase consisted of each participant rating 60 randomly ordered spatial scenes for perceived levels of envelopment and engulfment. The four spatial techniques were presented on the horizontal, elevated and 3D loudspeaker configurations five times each. The experiment lasted approximately 23 minutes. A ten second break was allocated between each scene for the first 24 scenes, a nine second break between each scene for the next 12, an eight second break for the next 12 and a seven second break between each scene for the remaining 12. The gradual shortening of breaks between scenes was applied as it was found in the pilot study participants did not need as long a break to complete the rating of each scene as the experiment progressed.

4. Experiment results

A Spatial Techniques (4) and Loudspeaker configuration (3) factorial analysis of variance (ANOVA) was performed on the envelopment and engulfment ratings. An alpha level of .05 was used for all statistical tests. The ANOVA results for the main effects are shown in Table 1.

Effect	df	*F*	*p*	η^2_P
Envelopment				
Techniques	3	30.003	< .0001	.246
Loudspeakers	2	1.577	< .017	.029
Engulfment				
Techniques	3	10.420	< .0001	.102
Loudspeakers	2	4.498	< .012	.032

Table 1. The ANOVA results for the spatial attribute of envelpment and engulfment reveals significant effects for the two indepentent variables: Spatial Techniques and Loudspeaker Configurations.

4.1 Envelopment

Results suggest a significant main effect for Spatial Techniques (F = 30, p < 0.001) (Table. 1) and a significant main effect for Loudspeakers configurations (F = 1.5, p < 0.017) for envelopment ratings (Figure 5.). A Bonferroni post-hoc test was performed to determine which pairs of means were significantly different for spatial techniques. Results indicate a significantly higher envelopment rating for the Dynamic Spectral Spatialisation technique M = 3.7 (SD = 0.62) over Amplitude Point Source Panning M = 2.9 (SD = 0.61) p = < 0.001, Spectral Splitting M = 3.0 (SD = 0.62) p = < 0.001 and the Timbre Spatialisation techniques M = 3.4 (SD = 0.54) p = < 0.003.

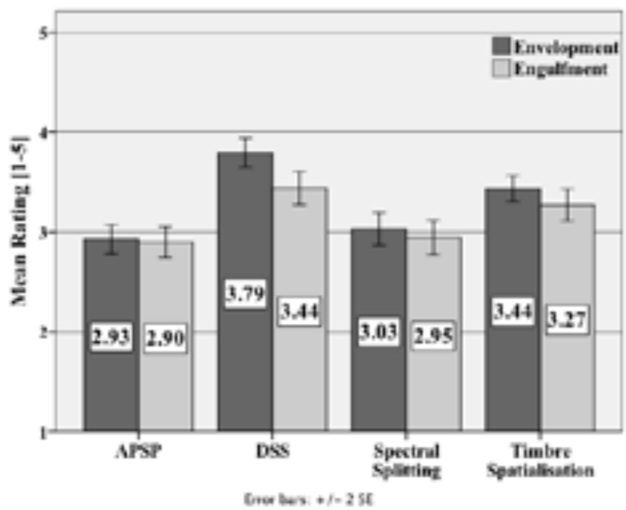

Figure 5. Envelopment and Engulfment mean ratings for each spatial technique; Amplitude Point Source Panning (APSP), Dynamic Spectral Spatialisation (DSS), Spectral Splitting and Timbre Spatialisation. The DSS technique was rated highest for both spatial attributes.

Furthermore, results from a loudspeaker post-hoc test suggests that the Horizontal M = 3.4 (SD = 0.70) was rated significantly higher than the Elevated loudspeaker configuration M = 3.1 (SD = 0.72) p = <0.013 for envelopment ratings.

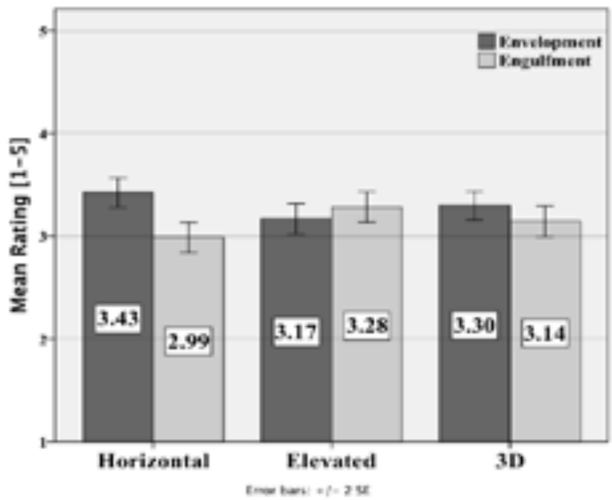

Figure 6. Mean ratings for Envelopment and Engulfment for each Loudspeaker configuration: Horizontal, Elevated and 3D. The Horizontal Configuration received the highest Envelopment rating and the Elevated configuration received the highest Engulfment rating.

When comparing means between each spatial technique in relation to each loudspeaker configuration, listeners rated the Dynamic Spectral Spatialisation technique highest for envelopment for Elevated (M = 3.7) and 3D (M = 3.81) configurations (Figure 7). The Timbre Spatialisation Technique was rated highest for Envelopment for the Horizontal (M = 3.74) configuration (Figure 7).

4.2 Engulfment

Results for engulfment ratings indicated a significant main effect for spatial Techniques ($F = 10.4$, $p < 0.001$) and a significant main effect for Loudspeaker configurations ($F = 4.4$, $p < 0.012$). A post-hoc test was performed to determine which pairs of means were significantly different. Results indicate a significantly higher engulfment rating for the Dynamic Spectral Spatialisation technique $M = 3.4$ ($SD = 0.65$) over Amplitude Point Source panning M =2.8 ($SD = 0.61$) $p = < 0.001$, Spectral Splitting $M = 2.9$ ($SD = 0.73$) $p = < 0.001$, but not for the Timbre Spatialisation technique $M = 3.2$ ($SD = 0.68$) $p = < 0.816$. When comparing means between each spatial technique in relation to each loudspeaker configuration, the Dynamic Spectral Spatialisation technique was rated highest for engulfment for Horizontal ($M = 3.20$), Elevated ($M = 3.68$) and 3D ($M = 3.44$) loudspeakers configurations (Figure 7.). Furthermore, post-hoc results for Loudspeaker configurations indicate that the Elevated M =3.2 (SD = 0.71) was rated significantly higher than the Horizontal loudspeaker configuration $M = 2.9$ ($SD = 0.71$) $p = < 0.009$ for engulfment ratings.

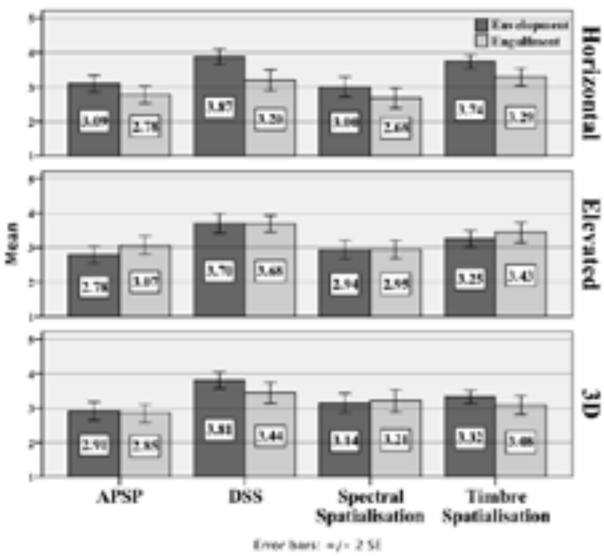

Figure 7. Envelopment and Engulfment mean ratings for each Spatial technique in relation to each Loudspeaker configuration. For Envelopment ratings, the Dynamic Spectral Spatialisation (DSS) technique was rated highest for Elevated and 3D configurations, and the Timbre Spatialisation Technique rated highest for the Horizontal configuration. For Engulfment ratings, the DSS technique was rated highest for the Horizontal, Elevated and 3D configurations.

5. Discussion and Further Research

Based on the above results, (i) the Dynamic Spectral Spatialisation technique was rated highest for levels of envelopment and engulfment, (ii) there is a strong correlation between the spatial attribute envelopment and the use of the Horizontal loudspeaker configuration, and (iii) there is a strong correlation between the spatial attributes of engulfment and the use of the Elevated loudspeakers.

This suggests that the Dynamic Spectral Spatialisation technique is the most effective spatial technique for creating a sense of envelopment and engulfment. The Timbre Spatialisation techniques received the second highest rating for envolpment and engulfment. Both of these spatial techniques use time-varying spectral processes to spatialize sound. This may be a factor why listeners rated these techniques higher then the Spectral Splitting and the Amplitude Point Source Panning techniques. An informal discussion with participants after the experiment had finished suggests that this was a reason why higher ratings were given to specific techniques over others.

A comparison of loudspeaker configuration rating means reveals that the Horizontal configuration was rated highest and the Elevated configuration rated lowest for levels of envelopment. A similar result was found by [15] which suggests that horizontal spatial scenes are perceived as more enveloping than 3D spatial scenes. For engulfment, the Elevated loudspeaker configuration was rated highest and the Horizontal rated lowest. This result further contributes to Sazdov's proposed definition description of elevated sound and the association of engulfment with elevated loudspeakers [18]. Research studies have suggested that listeners perceive engulfment and envelopment as two separate spatial attributes, with engulfment being an attribute that is unique to elevated sound [18,19]. What can be concluded from this research study is that elevated sound results in the perception of the spatial attribute of engulfment, and the use of horizontal sound results in the perception of the spatial attribute of envelopment.

A possible application of the research data would be to implement the most effective spatial technique and loudspeaker configuration for envelopment and engulfment. For example, using the rating means of spatial techniques in relation to each loudspeaker configuration (see Figure 7.), the Dynamic Spectral Spatialisation techniques in conjunction with the Horizontal configuration could be used to create a sense of envelopment and the Dynamic Spectral Spatialisation in conjunction with the Elevated configuration could be use to create a sense of engulfment. Another possibility would be to spatialize with two different techniques at the same time, one spatialised in the Horizontal and one in the Elevated configuration. By utilizing the entire 3D configuration in this way different ratings for envelopment or engulfment may be achieved.

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