# STIMULATION OF PSYCHOLOGICAL LISTENER EXPERIENCES BY SEMI-AUTOMATICALLY COMPOSED ELECTROACOUSTIC ENVIRONMENTS

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## ABSTRACT

This work represents the first steps in an almost completely unexplored field, in which electroacoustic composition, based on several signal processing techniques including additive synthesis, pitch extraction and bandpass filtering, is exploited to produce unique sonic environments for stimulating targeted listener experiences. We propose three semi-automatically composed electroacoustic environments and evaluate their psychological potential considering four areas: creativity, emotion, self-perception and mental associations. This empirical study uses a cross-modal perceptual test, completed by 100 listeners. Results presented indicate that electroacoustic music can successfully evoke specific colour connections and individual self-perception. Additionally, we show that synthesised sound based on bio-signals, such as a heart beat, can promote concrete thought and negative emotional states. Our future goal is to fully-automate electroacoustic music composition environments for use in therapy, education and entertainment to promote and encourage human well-being.

***Index Terms*****—** Technology for well-being, electroacoustic signal processing, cross-modal perception.

## 1. INTRODUCTION

Evidence shows that art and science can influence and inspire one another in many ways from therapy to entertainment. Whilst there are many scientific efforts which undeniably improve human well-being, there is also considerable evidence that artistic activity promotes positive psychological states and reduces adverse physiological outcomes [1]. This type of collaboration allows for new and innovative perspectives on research involving human well-being [2].

Our research, aimed at improving human well-being, falls within such an interdisciplinary vision. By integrating automated signal processing along with multimedia technologies, therapeutic methodologies and artistic environments, we believe it is possible to create a robust system to increase human wellness from a holistic point of view. With this in mind, this study proposes and explores a novel approach, to aid human well-being through the utilisation of semi-automatically composed electroacoustic environments. It is our belief that this interdisciplinary research has great potential, such as the development of an integrated system for mood and psychological improvement.

In engineering, the field of *embodied socially active listening* has recently begun to be explored. There have been attempts to recover an active attitude of music listening through associations between expressive movement and exploration of physical space [3]. Similar studies, which explore the relationships between movement, sound and emotional expressions, are from a scientific point of view, usually influenced by the embodied and reflexive interaction paradigm. This considers using physical metaphors (virtual copies of themselves), to improve learning and abstract thought [4]. Psychology has also explored manifestations between art and human well-being. For example, the *Videoinsight* method [5], is a new approach for psychotherapy which successfully integrates with digital art. This method is based on a capacity for contemporary art to stimulate; mental associations, creativity, communication, self-esteem and conflict resolution.

We consider that electroacoustic music has the same potential as contemporary visual art and, for this reason could be an effective tool within therapeutic or pedagogic settings. In this research we explore how electroacoustic environments, specifically composed through a variety of semi-automatic signal processing techniques, can influence a listeners perception and promote psychological experiences in several areas including: creativity, emotion, self-perception and mental association. The presented research is based on evidence from previous studies, which suggest connections between emotional intelligence and creativity [6], self-perception [7], and reflective thought [8]. In this paper we present and explore the effectiveness of electroacoustic environments for stimulation of specific psychological experiences in the areas mentioned.

The rest of this article is structured as follows: an overview of human perception of music (Section 2); a description of each sonic environment (Section 3); an overview of the perception test (Section 4); an outline of our hypotheses (Section 5); a review of the obtained results and discussion (Section 6); and finally, our conclusions (Section 7).

## 2. HUMAN PERCEPTION OF MUSIC

Whilst many researchers have explored music's emotional content and expression, there is no clear agreement of which exact musical parameters evoke emotion [9, 10]. Previous studies have evaluated listeners emotional response, which go beyond music itself, considering factors such as; musical performance [11] and structure [12]. The acoustic parameters which communicate emotional expressions in both music and speech is an active an ongoing area of study [13]. Indeed, tools commonly used in the field of emotional speech perception, has also been used in the evaluation of emotions in music; e. g., FeelTrace [14]. In comparison, there has only been a small amount of research that considers music perception from a cross-modal prospective, including its influence on; spatial ability [15], imagination [16], and colour associations [17]. We consider that a cross-modal evaluation of music perception is essential to understand the indirect mechanisms which influence how emotions in music are perceived.

Thanks to a vast array of pre and post signal processing techniques, including: sound synthesis, pitch extraction and low pass modulation, electroacoustic music can be characterised infinitely. This wide-range of sonic possibilities, generates great interest for the study of perception with in electroacoustic composition [18]. Despite this, there has been minimal research, considering emotional electroacoustic music perception [19, 20, 21]. Further, none of these studies conducted listening tests like those offered by this paper, since the perception of electroacoustic compositions in the psychological spheres of creativity, self-perception and abstract thought are explored herein for the first time.

## 3. ELECTROACOUSTIC ENVIRONMENTS FOR WELL-BEING

Throughout the 20th and 21st century, contemporary music has been sparsely used with in therapy. The music therapy method, *Guided Imagery and Music Therapy* (GIM) [22] is one of the few therapeutic practices that includes contemporary music as a tool. There is evidence shows that this GIM program can develop self-awareness, reduce stress and promote the resolution of conflicts [23]. Furthermore, the versatility of electroacoustic music encourages composers looking to evoke feelings or experiences in their listeners, also an desire commonly attempted in traditional music [24].

We propose three electroacoustic environments, which follow specific composition techniques to explore a listeners reaction in psychological areas including: creativity, emotion, self-perception and mental association. The term *proximity* is a descriptor used to express the physical distance each environment has to an individual listener. The *proximity* explored is based on the varying sonic textures, manually selected according to Benenzon's ISO theory (cf. subsection 3.1). *Minimum proximity* - includes samples taken from physiological

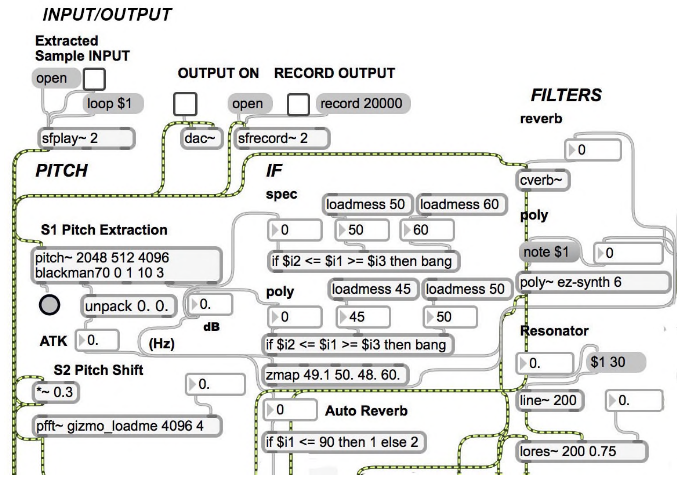


**Fig. 1**: Subsection of patcher, created using *Max* to produce a portion of the sounds used in Environment A. The heart beat heard (sampled from an online source), labelled here as 'Extracted Sample INPUT', has both the pitch (Hz) and amplitude (dB) values extracted using an external plug-in *pitch*. These values are then linked to a series of *if* statements which trigger events within specific filtering channels. For example when the amplitude is above a threshold, *spectral filtering* (another externally sourced plug-in by *Michael Norris*), is applied to the audio input.

signals, thus making it close to a listener. *Medium proximity* - includes real-life sounds, which could relate to specific cultural backgrounds. *Maximum proximity* - includes only synthetically produced sounds, which would not be familiar to most listeners since they are estranged from any physiology or cultural past. All of the pieces used are freely-available to the public and the scientific community and were originally composed by the authors.[1]

### 3.1. Composition techniques description

**Environment A:** (minimum proximity level), falls into the sub-genre of live electronics; this means that unlike the other two environments the foundation of this sonic environment was to be executed in real-time. In this case live electronics are guided by the signal of a pre-recorded heart beat sample which controls different sound processing events in a semi-automated manner. The use of a recorded heart beat as the control for other layers of sound generates a pseudo biofeedback relationship between the listener and the environment, developing and achieving the desired minimum proximity level. This technique is based upon Benenzon's conception of *Identidad Sonora*[2] (ISO) [25]. ISO is unique to each person and emerges from a combination of unconscious condensed energies typically attributed to human nature. Environment A, as it is based on a sound typical to a persons physiology, is a representation of *Universal* ISO [26].

[1]Environments are freely available: http://bit.ly/2n5sBYx
[2]Music Sound Identity

The foundation layers of this environment were produced using a script developed in the visual programming tool *Max* (cf. Figure 1). The patch manipulates the original raw audio with several filtering methods, including pitch extraction and resonators. In this case the resulting outputs were then mixed in *Logic Pro* where other post-processing was also applied, including: reverb, tape-delay and pitch correction. For ease of sharing the test, this environment was digitised and compressed as an *.mp3* file. It is worth noting here that our future work plans include exploring techniques which will enable us to recreate this environment as a performance.

**Environment B:** (medium proximity level), falls within the sub-genre of *Musicque concrete*. This considers the audio feed itself as the main source of the composition process [27]. The sounds used are recorded from real-life environments. The piece is then composed through the manipulation of the audio feed, from analogue tape (when this genre was established), to a digitised feed (modern time). Through this genre we created a sonic environment related to the *Cultural* ISO of a listener; an ISO related to sounds typical of peoples homogeneous cultural background [26]. For this reason the environment has a medium proximity level; the soundscape is 'further' from the listener compared to Environment A, but is still related to their *Cultural* ISO.

In order to create a connection between listeners and their cultural background regardless of nationality Environment B was created using sounds common to a range of different cultures and landscapes (rural and city), including: a busy market, the train station, calling cockerel, and church bells. Subtractive synthesis was utilised in order to create this environment. The raw sounds were automatically filtered through a script produced in *Max* which extracted only signals when the amplitudes were above a set threshold. This results in a choppy and somewhat scattered sonic results from the original source. The produced layers were then mixed and preprocessed manually using *Steinberg Cubase*.

**Environment C:** (maximum proximity level) is defined as *pure electronic*, as it was composed with only synthetic sounds. This is the sonic environment less related to the listeners ISO since the sonority of this is completely artificial. The semi-automatic composition technique used in this case was additive synthesis and the environment was created through the open source software *cSound*. A complex triangle wave produced by oscillators, was randomly distributed within a threshold of 50 per second. The wave had a fixed envelope size of 1.5 seconds, and only the first three resulting harmonics of each fundamental frequency were considered. Parameters were then locked for the number of oscillators, and fundamental frequencies and specific duration's were inserted manually.

Each environments unique frequency content is visually representing listener proximity (cf. Figure 2). The spectrogram for Environment A shows the broadest band of frequencies (marked in red) hence better mimicking a real-word sonic

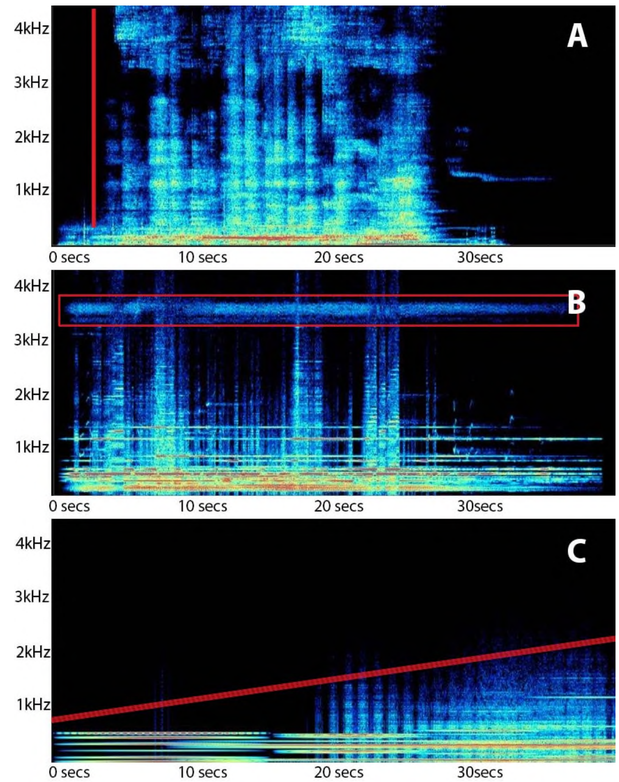


**Fig. 2**: Spectrogram of each sonic environment (A,B,C). The progression of each environment is also a prominent element to these spectrogram results. Environment A shows a sharp increase in frequency content which sustains throughout its entire duration, B is mostly consistent and C has a continuous increase.

environment. Environment B contains a similar bandwidth, but includes more strains of focused energy, marked in red on the spectrogram at 3.8kHz. While Environment C has less frequency content overall there is a continual increasing (marked in red) from peaks of approximately 800kHz, to around 2kHz, therefore quite dissimilar to usual sonic environments which generally contain vast amounts of complex noise.

## 4. CROSS-MODAL PERCEPTION TEST

The perception test was realised by 100 people, 48 males, 51 females and 1 other, from 20 different nationalities, with high prevalence in Spain, Italy, Germany and UK. Most of the listeners were aged between 25-35 (54%), and other age groupings were represented similarly (19%, 13% and 14% for 18-24, 36-45 and 45+ respectively). Participants were asked to listen to extracts (between 30-45 seconds) of each environment and fill out the corresponding perception test (therefore the same test format was submitted three times). The listeners were asked to use headphones to improve the listening experience. All participants were recruited on a purely voluntary basis; they did not receive a gift or gratuity upon completion. The test which was hosted using the survey tool *SurveyMon-*

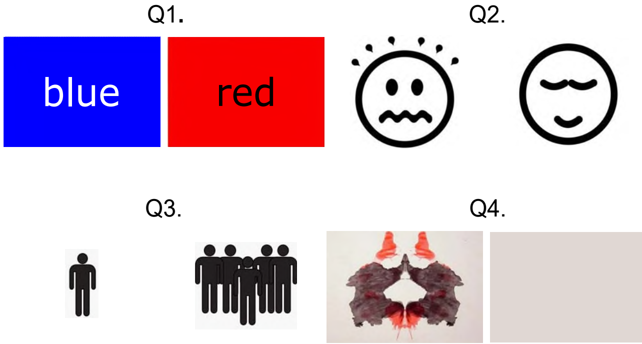


**Fig. 3**: Content used for the perception test. Q1 (creativity), considers two colours, blue as a cold choice, and red as warmth. Q2 (emotion), considers two facial expressions associated to either negative or positive emotion. Q3 (Self-perception), considers two choices, one person for individualism and group for collectivism. Q4 (mental associations), considers two images, one associated to an abstract nature (inkblot taken from Rorscharchs psychological test [28]) and another implying nothing (blank image).

*key*[3], was spread and realised completely on-line.

### 4.1. Test description

For the perception test (cf. Figure 3) we considered a novel approach that evaluates the presented environments influence in four psychological areas (creativity, emotion, self-perception and mental associations) chosen due to their importance in relation to human well-being [6, 7, 8]. For the listeners evaluation of each environment, relating to the following psychological areas, we used a four question bi-polar forced choice test.

- **Creativity:** evaluates the extent to which each environment induces synaesthetic colour connection (cold or worm);
- **Emotion:** evaluates the extent to which each environment evokes emotional reactions (negative or positive);
- **Self-perception:** evaluates the extent to which each environment stimulates the sense of belonging (individualism or collectivism);
- **Mental associations:** evaluates the extent to which each environment promotes reflective thoughts (abstract connections or no abstract connections).

To the best of the authors knowledge, this is the first study which evaluates the potential of electroacoustic composition to evoke specific connections within a psychological sphere of creativity, emotion, self-perception and mental-associations.

[3]https://www.surveymonkey.com/

## 5. EVALUATION PARAMETERS

Our research explores if, the changing level of proximity between listener and environment, has an influence on a listeners perception to a considered psychological areas.

For *creativity* (synaesthetic reactions) and *emotion*, as this is an innovative testing scenario, we cannot speculate which reaction a listener will have. This is due to an individuals answer being dependent on multiple factors, including personal preference or familiarity with electronic and avant garde composition. Therefore, results from this evaluation will give highly novel insights into how electroacoustic composition could be used for an array of purposes across different therapeutic, educational or recreational scenarios.

For the ability of the environments to evoke experiences related to *self-perception*, we speculate that a sense of belong will be promoted gradually through Environments A, B and C; from A (identifying with mostly collective thought) to C (identifying more strongly with individuality). This speculation is related to the proximity level of environments. Minimum proximity, related to the universal ISO, will promote collective thought. Whilst maximum proximity, not related to the listener's ISO, will promote individual thought.

For the ability of the environments to evoke *mental associations* we speculate that abstract thought will be progressively present across Environments A, B and C. From A (showing dominantly abstract associations) to C (showing less abstracted thought). This speculation is again related to proximity level. A minimum proximity will more easily promote mental associations, since sounds used are related to a listeners ISO, which are closely linked to ancestral memories. Whilst maximum proximity, due to the absence of ISO in synthetic sounds, will be unable to promote these.

We use the *Chi-Squared* test (for univariate categorical data) to evaluate if there is a significant difference in the responses to each specific question. We interpret the returned p-values in the following manner; $p > .05$ indicates result is not significant, $p < .05$ indicates result is mildly significant, $p < .01$ indicates significance at a moderate level and $p < .001$ indicates significance at a strong level.

## 6. RESULTS AND DISCUSSION

Examining the connections between the environments and synaesthetic perception our analysis revealed a significant relationship between the three environments and the cold colour choice, blue (cf. Figure 4). This significance was at a moderate level for both Environments A and B; 64% ($p < .01$) of respondents made the blue association for both pieces. This association was only mildly significant for Environment C where 62% ($p < .05$) of respondents made the association. These results, especially Environments A and B, indicate that electroacoustic sonic environments can be used to evoke synaesthetic connections. Potential applications of

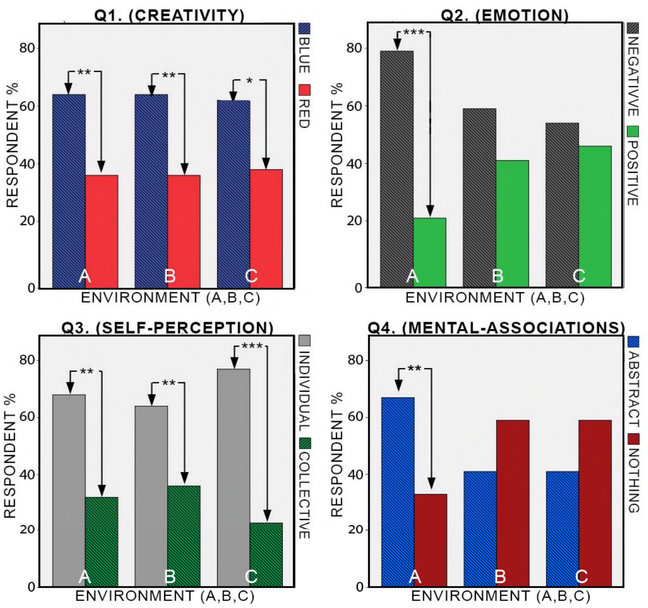


**Fig. 4**: Bar Graphs showing the listeners responses across all environments and perception tests. The stars are used to highlight statistical significance; * indicates mild significance, ** indicates moderate significance and *** indicates strong significance.

pieces with this significance could include, relaxation in therapy to ease tension and anxiety [29].

We also explored the connection between environment and emotional perception (cf. Figure 4). Our analysis reveals a strongly significant relationship between Environment A and negative emotional perception; 79% ($p < .001$). Negativity was also the dominant choice for Environments B and C, 59% and 54% respectively; however, these association were not significant. Given that there are strong association to negativity in Environment A, this environment could be used to exemplify and project negative experiences, promoting the expression of suppressed feelings and the resolution of personal conflicts. With in secure surroundings this could assist in solving negative states for both therapeutic and educational purposes. A similar technique is successfully used in *Jungian play therapy* [30].

Our analysis of the connections between the environments and sense of belonging did not yielded the results we expected (cf. Figure 4). Whilst, as expected, Environment C promoted individual sensations with strong significance levels, 77% ($p < .001$); Environments A and B also show a significant predisposition to the induction of individualism – 68% ($p < .01$), and 64% ($p < .01$) respectively. Since the tendency of all three environments is to evoke individualism, we speculate that electroacoustic music itself may be the basis of this disengaging effect. The use of these environments in promoting self-perception may help individuals with pathological altruism, to improve self-esteem, assisting in combating an inability to perceive strengths without the help others.

Finally, as speculated Environment A promotes experiences relating to the development of abstract thought. Our analysis shows this relationship to be of moderate significance with 67% ($p < .01$) of respondents making this connection. Although, as anticipated, there was some abstract thought promoted by Environment C it was not significant – 59% ($p > .05$). Environment B also did not show a significance to abstract connections, also 59%. Environments, like A, that promote abstract thought, could as an example, be useful in treatments for children with learning difficulty, in order to improve mathematical skills and high-level language usage (as metaphors are).

## 7. CONCLUSIONS

In this paper we presented evidence of how, semi-automatically produced electroacoustic environments are able to promote precise psychological experiences within areas of creativity, emotion, self-perception and mental associations. Such sonic environments have a variety of potential applications, in; education, therapy or entertainment where human well-being, emotional intelligence and enjoyment can be a predominate part of their mission.

Of particular excitement was our live electronic environment (Environment A), created using a heart beat sample as the fundamental sound. This piece was able to effect listeners significantly across all of our evaluated psychological areas: encouraging cold colour synaesthetic connections, negative emotional associations, abstract thought, and individualism. Our future goals include the use of live electronics monitored by biological signals to develop user-sensitive tools.

Other future goals include the fully automatic composition of electroacoustic environments and to elaborate further on cross-modal perception tests considering new parameters. We will also consider the integration of these environments with in multimedia technologies to create multidimensional settings which can contribute to human well-being.

## 8. ACKNOWLEDGEMENT

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