

# DIVERSIONARY SPACE PROJECT AT ROYAL MELBOURNE HOSPITAL SHORT TERM DEMENTIA WARD

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## KEYWORDS

Sound Design, Sine Tone, Dementia, Constructed Environment

## ABSTRACT

*This paper outlines and discusses the processes and potential outcomes of the Diversionary Space Project at Melbourne's Royal Park Hospital. This project is being developed in partnership between the VCA School of Production, the School of Behavioural Sciences at the University of Melbourne, the National Aged Research Institute (NARI) and the Royal Melbourne Hospital. In this project we intend to use simple pure sound waveforms to sonically excite a specific space in the short-term dementia ward of the RMH. This project is yet to be completed.*

*So far, little data on the effect of this kind of constructed sonic environment on dementia patients has been found. We are looking at developing and exploring strategies and methodologies for enhancing a specific space sonically, and, where possible, evaluating appropriate data gathering and interpreting systems. It is anticipated that this pilot research carried out in the health environment will be expanded to other environments, such as the constructed environment and the arts.*

*Here we will discuss: the background to the project, its description, processes, intentions and goals. We will also be discussing the deliberate use of constructed sound in the board environment, the physiological response to music and sound, sound perception and propagation, and potential outcomes and methods of evaluation.*

## **BACKGROUND TO THE PROJECT**

The Royal Melbourne Hospital offered funds to develop a design to enhance part of a dementia ward. Through various funding arrangements the project was offered to Victorian College of the Arts School of Production, where graduate and under graduate students were asked to produce elements that would ameliorate and enhance a walkway in the Short Term dementia ward Ac1. In her application for ethical review of the project Dr Dina LoGiudice described the corridor as one „which looks to the outside [, and] is used frequently by those who tend to “wander”. There have been plans to aesthetically improve this space as a diversional area for the clients, introducing physical themes that tap into familiar scenes and environments.”(LoGiudice 2008).

It was decided to use both sound and physical objects in improving the space, creating localised visible, tangible objects, and un-localised, intangible objects, the sound-scape; we are discussing the sound portion of the larger project here.

Introducing a non-tangible object has many benefits in a situation such as this: it is very easy to transport, the infrastructure costs are comparatively small, it can easily be replicated and adjusted to new physical environments, and it is easy to adjust as the client/user base changes, and in response to the effects of the sound design on the client base. A sound design is also transferable to other environments and situations, meaning that it can easily be installed in similar situations to that at the RMH Ac1, or different, less similar situations, such as building foyers, courts, transit lounges and so on; anywhere in which an environment may require amelioration in order to improve the experience of that environment for its inhabitants.

We also considered ways to develop a qualitative approach to gathering data related to the project. To this end we asked Dr Neil McLachlan (Behavioural Sciences UoM) to be involved, and he offered a system through which movement could be monitored through a video camera, and the resultant data is stored in a usable fashion. This process uses non-identifiable tracings of movement and presents the resulting information in a way that can be easily parsed and quantified, thus creating an opportunity to see trends in the motion of the clients in the RMH dementia ward Ac1. This process is currently in development stages, and it is intended that it will be deployed in other situations and environments, such as those mentioned above. It is hoped that after acquiring sufficient preliminary information and data it will be possible to extrapolate further uses for the system, or similar systems, and to enhance its projected medical, and other, uses.

## **RELATIONSHIPS TO SOUND IN OUR ENVIRONMENT**

People are very much accustomed to existing in an aural environment. We use music as a way of acculturating ourselves, and to condition our environment. The near ubiquity of iPod and similar technologies indicate how the personally created aural environment is often preferred to the actual or natural aural environment. This aural conditioning is used, for example, to trigger memories, to abstract ourselves from our immediate situation or environment, create a „mood”, and in creating social cohesion and distinctiveness. Many aspects of this list relate to the use of music, where the sounds that are created through that medium are easily recognised and understood. For example; the piano music of Ravel may be used to create a romantic or relaxed mood, or the music of the Sex Pistols to create a more energetic mood.

Sound is also our primary alarm system, alerting us to potential dangers that are not in our fields of vision or touch. The ability of sound to give us multi-dimensional awareness (up, down, left, right, in front, and behind) of our environment and characteristics of the things within it makes it a very useful tool in adjusting or influencing a sense of the environment(s) we are inhabiting and experiencing.

Sound is very useful in localising one's physical position; aural cues, for example, give a sense of the dimensions of our immediate environments and our position in it; for example, we can very easily point to an object we hear, regardless of its position and often with as much accuracy as one that we see. The process of listening to a space is also used by the vision impaired as an aid in navigating and gathering cues regarding their environment (Kemp 1983; Grabowski & Barner 1998). This is done through paying attention to the sounds reflected off objects in the physical environment, the reverberation.

The music and sound recording industry uses reverberation to create a sense of the environment the musicians and producer want us to feel we are in. Programs such as Space Designer (<http://www.apple.com/logicstudio/effects/#space>), IR-1, (<http://www.waves.com/Content.aspx?id=277>) and Altiverb (<http://www.audioease.com/Pages/Altiverb/AltiverbMain.html>) use the sounds of specific spaces to create a convincing aural sense that we are in that space, be it a rain forest, the Notre Dame Cathedral, or the Ryman Auditorium.

In the cinematic arts sound is considered as having a fundamental, „sublime power ..., considering the revolutionary potential it holds for rewriting the meanings of film“ (Sinclair 2003). It is used to heighten emotions in the viewer/listener and reinforcing, or counterpointing, its visual /textual narrative, adding considerable depth and information to an experience we often consider as being primarily visual. (Baumgartner, Lutz et al. 2006) The most obvious example of this is the pianist accompanying silent movies, where it was quickly recognised that the visual image itself was best experienced when informed and enhanced with sound.

As mentioned above, sound is very effective in creating moods, generating memories and so on. The sound of surf breaking on a beach can evoke a sense of freedom and relaxation, or memories of childhood vacations; or the sound of footsteps may evoke fear or familiarity, depending on context and the very personal experiences of the individual hearing those sounds. These uses indicate the potential value of non-musical sounds in creating an experience of an environment.

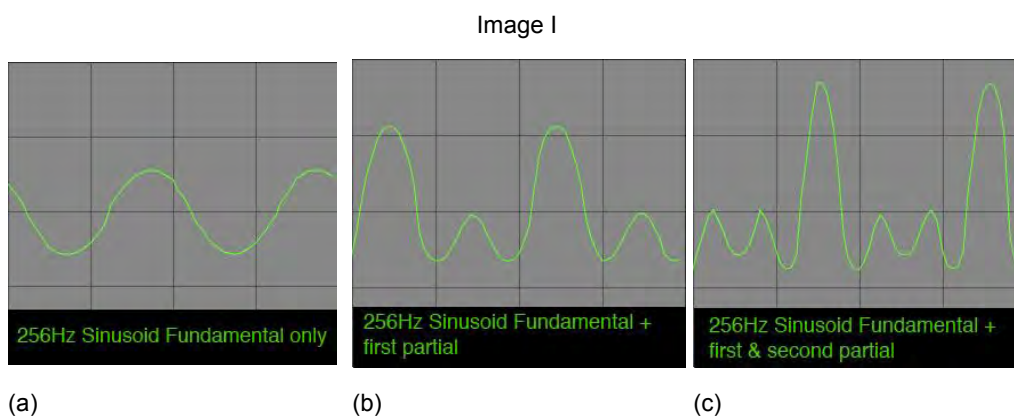
Our relationship with our aural world is subtle and often ignored, yet it is possibly one of the most powerful and profound relationships we have with both our internal, personal and subjective environment, and our external, social, and objective environment. In the cases mentioned the sounds are easily identifiable, providing a direct reference to the object(s) that they signify.

Here the sounds that we will be using are not so easily recognisable or identifiable; instead the sounds we intend to broadcast are low amplitude, simple tones, and this is a unique characteristic of this research path. What we will be exploring is the use of sound as a method through which to contribute a non-obtrusive element in an environment. It is important that this element does not directly or overtly intrude on the environment or prescriptively influence the behaviour of its inhabitants. Instead the goal is to subtly add an element to the environment and to quantifiably explore the influence it has on the space and behaviour in it. As people move within the environment they will perceive changes in the sounds as those sounds reflect off the walls and the

person changes the relationship of their ears to the broadcast and reflected sounds, an explanation of the relevant physical principals of sound and the physiological responses follows.

Relevant principals of sound: physics and perception.

Physics of sound states that sound waves consist of fluctuations in air pressure created by vibrating surfaces. A simple sound wave can be described as a sine wave having specific frequency, amplitude and phase. According to Fourier theory<sup>j</sup>, a complex wave can be regarded as a collection of many simple sine waves added together, and can be deconstructed into pure tone components which can be shown to bear integer multiple and simple ratio relationships to the fundamental (strongest) frequency; for example, the upper components (harmonics or partials) of a tone with a fundamental of 100Hz would occur at 200Hz (2:1), 300Hz (3:2), 400Hz (4:3) and so on. With each additional partial, the tone becomes more complex. The complexity of the tone is also dependant on the amplitude of each partial. The following diagram, showing a frequency of 256Hz, represents (a) a single tone with the fundamental pitch only, (b) the fundamental plus the first partial at equal amplitude, then (c) the fundamental plus second and third partial at equal amplitude. Notice how the waveform becomes more complex in nature with the addition of each partial.



Fourier spectra and spectrograms offer graphical representations of the sine-wave frequency components of complex sounds. Any transmitting device or medium can be viewed as a filter that preserves some Fourier components in a sound, and attenuates or removes other components. The transfer function of the filter defines its ability to transmit sound components at different frequencies. Fourier theory can be used to characterise a filter's properties only if the filter can be assumed to be linear. The output of non-linear filters contains frequency components that were not present in the input. The auditory system can be viewed as a complex processing system that contains both linear and non-linear components.

In *On the Sensation on Tone ...*, Hermann Helmholtz (1885) conducted controlled experiments on the combinations of tones, and determined that the simpler the ratio between the two fundamentals, the more commonalities between two separate tones, and by sharing multiple frequency components, the tones would appear more pleasant to the ear. Where the two tones share fewer frequencies, a rougher and more complex (dissonant) combination tone would occur. Further sophistication of our understanding of how we perceive sound when multiple tones are combined, such as two notes played on a polyphonic instrument such as a piano or guitar, or notes played by multiple monophonic instruments (trumpet, flute etc) was articulated by Fletcher (1940)

who showed that when we have two tones, the relationships of their fundamental and subsequent partials can produce very complex tones. Fletcher introduced the concept critical bands, which are a range of frequencies either side of a fundamental or upper partial. The range of critical bands can act like an auditory filter, and vary according to the tone. If critical bands are adjacent but not identical, the resultant accumulation and beating of the tone within the critical band is perceived as dissonant or unpleasant. More recent studies have reinforced the fact that humans can make very subjective judgments on the acceptability of sound stimulus when simple tones of relative ratio are used. Schellenberg & Trehub (1994) tested a wide range of subjects and listening tasks and found that „simplicity of frequency ratios accounted for judgments of consonance and dissonance and for judgments of similarity across a wide range of tasks and listeners. It also accounted for the relative ease of discriminating tone patterns by musically experienced and inexperienced listeners. These findings confirm the generality of previous suggestions of perceptual processing advantages for pairs of tones related by simple frequency ratios.“

## PURE TONES

There is no natural existence of a pure tone; that is, a tone with even cosine relationships. All natural sounds are at least complex in spectrum, ranging from complex to very complex. Pure tones can only be synthesised electronically. The absence of pure tones in nature is due to many things, including:

- The complex anatomical construction of physical matter that, when force is applied, resonates with a complex spectra,
- The characteristics of sound propagation in an environment and the accumulated reflections
- The phase effects, cancellations and critical band distortions as introduced by Fletcher.

Pure tone is therefore appropriate for constructing controlled environments as it is the most convenient to test, measure and analyse. Pure tones have been used extensively in tests and experiments in psychology. In the Handbook of Psychology (Weiner et al. 2003) numerous references are made to the pure tone as a means for testing the auditory perception of humans, as well as a host of other animals including frogs and cats. Pure tones are central to explaining psychoacoustics. In *Signals, Sound, and Sensation* (Hartmann, 1997), the author uses the Fourier transform theory to unify topics as diverse as cochlear filtering and digital recording.

Sound propagates in space in several ways, namely reflection, refraction, dissipation and absorption. These propagation characteristics are filters that can add or remove components of sound. Reflection bounces sound around a space, creating multiple paths other than a direct path from the sound source to the ear, and can modify (increase or decrease) the amplitude of certain frequency components. Refraction refers to environmental issues including humidity and wind that can affect the direction that certain components of sound can travel, acting as a filter as it masks, detours, or amplifies certain frequencies but passes others. Dissipation occurs when objects of certain dimensions impact upon the path of the sound wave, in relation to the wavelength; for example, pillars in concert halls will dissipate high frequencies with a wave length similar to the object. Absorption also works according to the relationship between wavelengths and material, with some material absorbing certain frequencies more than others, subsequently affecting the sound in a space. There has been much research in the way sound propagates in space, and how the ear locates and processes this information, but, at this point of investigation, there seems to be little evidence of specific studies on production of sine tones, the effect of environmental filters on sine tones, and how they impact upon auditory perception.

## **PHYSIOLOGICAL RESPONSE TO MUSIC AND SOUND**

Auditory stimuli have been shown to have a profound impact upon the human physiological state, including behaviour, emotional response, relaxation and wellness (Krout 2007). It has been suggested that music can have a positive effect upon both neural functions and hormonal activity, including emotional responses involved in these processes (Schneck & Berger 2006). Researchers have only recently started to investigate the neuronal dynamics involved in processing music and sound stimuli using imaging techniques (Altenmüller 2004), and have identified the limbic system, located near the cerebral cortex and responsible for emotions, as being heavily involved. Altenmüller's work found that each person processes music uniquely; therefore no universal rules on the way the brain processes music, and consequently sound, apply.

Personal life experiences, memories, and levels of stress, excitement or fatigue, environment, or other people affect the way the brain processes sound. A considerable review of existing work on the physiological effects of auditory stimuli (mostly music) dating from late 1800s is found in Bartlett (1996) who states „some of the questions researchers of physiological response seek to answer are whether music has a measurable, thus observable, effect on the human organism and whether such effects can be evaluated in terms that help our understanding of music's "power" to activate and alter the human condition". While this may be the motivation behind these studies, it seems the works referred to by Bartlett predominantly use intrusive measuring devices to monitor parameters such as heart rate, respiratory rate, blood pressure, muscle tension, skin temperature, papillary reflex and hormone secretion. These measurement practices require the subject to be stationary and somehow physically attached to measuring devices, severely limiting the macro-physical or motor responses to stimuli. More work is required to measure the uninhibited actions of subjects to control their own physical responses to aural stimuli. Lagarde & Kelso (2006) stated that „very little is known about the coordination of movement in combination with stimuli such as sound and touch".

It is broadly accepted that the current predominant sense in modern Western societies is visual. It is through the reliance on technological revolutions such as the printing press and the personal computer, that Western society has been transformed from a predominantly aural to a predominantly visual culture (Classen 1993; Crosby 1998). In the context of human evolution, this is a very recent shift, and it would be incorrect to assume that human auditory capacity, as developed over millions of years as a primary communication and survival device, is now dormant or ineffective.

In the study of non-Western cultures, ethnomusicologists have established that music „is variously used by cultures to restore balance between people and their environment" (Stobbard 2000) and as a therapeutic tool in the healing process. (Friedson 1996; Janzen 2000; Roseman 1993). These studies are reported in Gouk (2004) who states, „that one of the most important functions of "music" is as a vehicle for altering spiritual states". The cultures related to in these works range geographically from Central Africa to Malaysia and Bolivia, and have evolved in relative isolation from one another, suggesting that there is a global relationship between the fundamental human spiritual state and auditory music and sound stimuli.

## **THE USE OF SOUND IN HEALTH CARE**

Contemporary Western medicine has recently seen a shift toward concerns regarding the spiritual states of patients. Contemporary Western hospital and healthcare settings are often large scale, depersonalising, chaotic

and uncomfortable environments that may, due to these circumstances, negatively affect the healing person's process. A systematic review of literature on the impact of art, design and environment on mental health (Daykin et al.2008) concludes that „environmental enhancements can have a positive impact on health and well-being of staff and patients in mental healthcare“ indicating a need to ameliorate the effects of these healthcare environments through enhancements of some kind, and that „there is still a need for further research that addresses methodological challenges of evaluating complex interventions“.

In healthcare, approaches to the application of music and sound based interventions have been acknowledged as an effective means for ameliorating the effects of various conditions and healthcare environments and enhancing wellness, stress reduction, and relaxation by providing active diversions such as singing, playing or making music, to receptive and passive activities such as music listening (Krout 2007).

As the ageing population increases, there are calls for new, innovative and safe ways to address the care of aging patients, and in particular those with dementia (LoGuidice 2008). There is an increasing body of evidence describing the need to address the design of clinical settings for those with dementia, in maintaining general quality of life and functioning for the older person (Wilkes, Flemming & Le Miere 2005). This includes the call for enhanced environments, and better-built environments, outlined in the two points that follow:

1. Enhancing the environment of the nursing home or hospital ward has been shown to have positive effects on patients, families and staff. One study by Cohen-Mansfield & Werner (1998) reports on the effects of enhancing a nursing home environment by simulating two environments – a home environment and a natural outdoor environment. Visual, auditory and olfactory stimuli were used in each. The report suggests that residents, their families and nursing home staff preferred to inhabit the simulated environments. Other studies of multisensory stimulation such as inclusion of a Snoezelen room, has shown some potential in ameliorating BPSD (Behavioural and Psychological Symptoms of Dementia). Originally designed in Holland, these rooms are used to promote relaxation in people suffering from sensory and learning disabilities. The idea has migrated from the initial treatment of children with learning disabilities to the treatment of dementia patients. The rooms provide a focused, relaxed, sensory experience that stimulates the primary senses of sight, hearing, touch and smell. Snoezelen explores the use of a mixture of sounds, lights, tactile stimuli and environment that capitalises on the residual sensorimotor abilities of people with dementia. There is also control over lighting and audio levels. The rooms can operate as silent environments, or music can be played. There are no guidelines to what music can be played; however there is an assumption that the music would be gentle western classical or „new-age“ relaxation music. Environmental sounds such as bird calls and waterfalls can be employed along with images of forests and oceans to provide dementia patients with a referential experience that may promote recollection of similar environments from their life experience, or simply act to provide a comforting and relaxing environment. It is a difficult area to measure as many different forms and combinations of environmental manipulation exist. A Cochrane review (Chung & Lai 2002) indicated promising results, but only 2 randomised control trials are available, yet other studies demonstrated within-session positive results for symptoms such as aggression, apathy and depression (van Weert et al. 2005; Livingston et al. 2005). Referential sounds have been employed to assist in the regeneration or reconnection with memory of dementia patients (Nagahata et al. 2004), such as the sound of horse hooves, trams bells, wood saws, or specific sounds that may invoke memories such as kitchen work, old routines and moments of nostalgia. Cohen-Mansfield & Werner (1998) found that

constructed referential environments reduced the agitated pacing behavior in some nursing home residents.

2. There is widespread acceptance of the need to control unwanted background noise in healthcare environments. Dementia wards are often busy, chaotic places with a high level of background noise. Most wards are not architecturally designed with much consideration of the aural senses or environment, and often amplify rather than reduce sounds due to the principals discussed above. It has only recently been recognised that improvements to the quality of care, and improved workplace for healthcare providers, can be achieved when facilities are designed with sound management in mind. Zarit & Zarit (1998) state that the importance of spaces free from background noise is essential to effective treatment and assessment of patients in nursing homes. The authors provide first hand testimonials on the contrasts in background noise between nursing homes in Sweden and United States, suggesting that in Sweden, lower levels of background noise has led to improved behavior among residents and a subsequently better quality of life. For staff, this creates a safer, more amenable workplace. A study by Burgio and associates (1996) suggests that background noise in a residential setting may be related to agitation.

No literature in the use of pure, simple tones in enhancing an aged care or dementia treatment environment has been found. It neither fits the traditional criteria of music as used in music therapy in either active or passive modes, and does not fit with the use of explicit referential or simulated environment sound therapy.

## **DESCRIPTION OF THE PROJECT AND PROCESSES USED**

The way we intend using sound to enhance the corridor space in the AC1 corridor, shown in Image 2 below, is to place a speaker at either end of the corridor and broadcast low amplitude, synthesised sounds from each speaker. These sounds will be slightly different in amplitude and lowest, or fundamental, frequency and related harmonic spectra. Typically, this kind of sound is not usually considered as „music“, such as that of the Sex Pistols or Ravel, nor does it seek to represent other absent sound sources, such as surf or footsteps. Instead it will create a subtle change in the ambience that may be not be easily perceivable, but will reside in a more liminal awareness.





Image II

The signal from each speaker will propagate throughout the space and merge with the signal from the other speaker to create more complex and diffused waveform characteristics as it moves through the space. Specific points along the corridor will be identified for measuring the waveform characteristics using Fourier spectrograms. The tonal attributes will be set for a specific period of time. These time periods will last at least one week or more with the same tonal attribute setting in effect. This provides an understanding of the waveform characteristics present at particular coordinates along the corridor at particular times and allows the clients of the Ac1 to become more comfortable and acculturated to the new element in the space. The specific waveform characteristics for each time period are yet to be determined, but current considerations include three contrasting tonal attributes being:

1. Simple, sustained, related waveforms
2. Slightly more complex sustained, related waveforms, and
3. More complex, undulating, fluctuating waveforms

Measurements of the third tonal attribute above will be based on measurements taken over the duration of a prescribed sound file duration (1 hour for instance) in order to later map periodic sound measurement data against video motion data.

The video motion data will be captured using an existing video camera and additional computer equipment. The actual video image is not stored. The software involved simply identifies (tags) individual objects moving in a physical space and generates time-stamped data based on the motion of each tagged object. The data collected during each period of particular tonal attribute will be compared and analysed against data collected during other time periods, including data collected before and after the introduction of the enhanced sound environment. This data will be analysed in conjunction with the RMH, NARI and Behavioural Sciences, University of Melbourne.

The staff attached to the Ac1 ward will also collect base-line data and monitor the installations as it evolves, ensuring that the safety and wellbeing of the clients is upheld and offering qualitative information where appropriate. Open-ended interviews will complement the statistical data with narrative experiences of the installation. The installation is planned for early 2009 with measurement and assessment continuing through 2009, followed by a period of data collating, analysis and comparison.

## **POTENTIAL OUTCOMES AND EVALUATION**

Principal healthcare provider at AC1, Dr Dina LoGiudice, and Dr Bruce Barber, chief research fellow from the National Aged Research Institute (NARI) are involved as associated experts in the area of aged care, and both see the importance of exploring new, innovative and safe ways to address issues in the care of those with dementia as the ageing population increases. They see the potential for immersive, liminal sound environments to have a positive effect on some symptoms of dementia, such as agitation, aggression, depression, delusions, sleep disturbance, and wandering, and it is hoped that this project may offer a potential paths towards this end. There may also be beneficial effects in other health care settings, such as palliative care, improving patient environments, or in mental health.

As clients traverse the corridor, changing, liminal sonic environments will be encountered, and clients will have the opportunity of effecting their small, local sonic environment simply by placing themselves in a place they feel more comfortable in; doing this simply by moving through the space to find the most pleasant mix of the sounds being broadcast.

The other strand being explored here is the use of the process of measuring movement trends within a specific environment, and the amount of time clients spend in specific areas within that environment. This will afford greater quantitative knowledge of spatial/human relationships and the intuitive, subconscious ways the environments are traversed.

When evaluating this pilot project we will use the data gathered from the motion capture systems to locate clients in specific areas of the corridor and cross-reference their positions with the specific sounds heard at those positions. As the sounds will subtly, and continually change according to position in the corridor we will use sophisticated sound analysis software and hardware to make accurate Fourier analysis of the sounds heard in each position where the clients seem to either stop or linger. We will assume that these positions are more conducive to a sense of comfort or preference for the clients. We will also cross-reference this with anecdotal and qualitative information from the staff working in Ac1.

From this point we will be taking the initial information gained here and extrapolating other possible experiments and uses of liminal sound in other environments, such as those mentioned above.

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### **Notes**

<sup>i</sup> A comprehensive explanation of Fourier theory can be found at “An Intuitive Explanation of Fourier Theory” <http://sharp.bu.edu/~slehar/fourier/fourier.html>