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Communicating Auditory Impairments Using Electroacoustic Composition

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Changes in human sensory perception can occur for a variety of reasons. In the case of distortions or transformations in the human auditory system, the aetiology may include factors such as medical conditions affecting cognition or physiology, interaction of the ears with mechanical waves, or stem from chemically induced sources, such the consumption of alcohol. These changes may be permanent, intermittent, or temporary. In order to communicate such effects to an audience in an accessible, and easily understood manner, a series of electroacoustic compositions were produced. This concept follows on from previous work on the theme of representing auditory hallucinations. Specifically, these compositions relate to auditory impairments that humans can experience due to tinnitus or through the consumption of alcohol. In the case of tinnitus, whilst much is known about the causes and symptoms, the experience of what it is like to live with tinnitus is less explored and those who have acquired the condition may often feel frustration when trying to convey the experience of 'what it is like' for them. In terms of impairment from alcohol consumption, whilst there is much hearsay, little research exists on the immediate and short-term effects of alcohol consumption on the human auditory system, despite over half of the UK population reported as consuming alcohol in 2017. The methodology employed to design these compositions draws upon scientific research findings, including experimental and explorative studies involving human participants, coupled with electroacoustic composition techniques. The pieces are typically constructed by mixing field recordings with synthesised materials and incorporating a range of temporal and frequency domain manipulations to the elements therein. In this way, the listener is able to experience the phenomenon in a recognisable context, where distortions of reality can be emulated to varying degrees. It is intended that these compositions can serve as easily accessible and understood examples of auditory impairments and that they might find utility in the communication of symptoms to those who have never experienced the underlying causes or conditions. This presents opportunities for pieces like these to be used in scenarios such as education and public health awareness campaigns.

Auditory impairment. Electroacoustic composition. Tinnitus. Hearing. Sound. Music.

1. INTRODUCTION

Auditory impairment, the reduction in efficacy of the human auditory system, can have many causes, manifests itself in a variety of forms, and be of a temporary or permanent form (Eggermont 2017). In this article, the primary concern relates to impairments in hearing due to either tinnitus (Eggermont and Roberts 2004) or the consumption of alcohol (Upile et al. 2007).

The number of people affected by tinnitus worldwide is estimated to be between 10 and 15% of the adult population (Baguley, McFerran & Hall 2013) and around 10%, or 6 million people, in the UK (Action on Hearing Loss 2017). It is commonly associated with ageing or the exposure to noisy environments, though it has other causes.

In the case of hearing impairment due to consumption of alcohol, it is harder to establish the numbers of population affected, since the effect is not as well documented and less likely to be noticed due to the intoxication. However, it has possible incidence in large quantities of the population. In the UK for instance, over 50% of the population, around 29 million people, reported that they consume alcohol (John 2018).

The contents of this article are the result of two principal drivers. First, the wish to raise awareness of these hearing impairments by works that are broadly accurate and reflective of the perceptions of people affected by them. Second, to explore through this creative practice, the ways in which sound and soundscapes can be produced to best

highlight the defining features of each impairment. As such, it is a natural extension of related work that explores the representation of changes in hearing perception due to other forms of intoxication (Weinel, Cunningham & Griffiths 2014, Weinel 2015).

The remainder of this article is organised as follows. Sections 2 and 3, respectively, provide an overview of tinnitus and alcohol related hearing impairments before detailing the process of creating electroacoustic works that reflect each. Finally, section 4 provides critical reflection upon the pieces created and suggestions for future work.

2. COMPOSITION: EFFECTS OF TINNITUS ON HEARING

Subjective tinnitus typically manifests itself as a noise that is perceived by the person with the condition but without their being an external stimulus creating the sound. The noise perceived by the person affected often takes the form of a tone, ringing, or hissing (Baguley, McFerran & Hall 2013). In addition to the hearing impairment produced, tinnitus may have negative effects upon the quality of life for the individuals living with it (Schaette 2014).

Of particular concern here is the experience of people living with tinnitus, particularly what the phenomenon that they perceive sounds like to them. Eggermont and Roberts (2004) give some indication, at least in terms of the frequency components, which constitute the sensations associated with tinnitus. Their study of ten subjects indicates that the frequencies most associated with being similar to a person's tinnitus are typically synonymous with the frequencies of their hearing that are most impaired i.e. where the threshold of audibility is greatest. In the subjects evaluated this was most notably at frequencies of 4 kHz or less. However, qualitative data, regarding self-reported experiences of what an individual's tinnitus sounds like is thin in the literature, with a performance autoethnographic report by Wheeler and Hopwood (2015) being a notable exception.

During a related research study (as yet unpublished), undertaken in cooperation with *Action on Hearing Loss Wales*, which investigated the experiences of people living with tinnitus, a series of qualitative descriptions of participants' tinnitus were obtained. In total, 213 people participated. Specifically, in relation to this work, participants were asked: *Describe what your tinnitus sounds like.* In addition, information about the nature of each individual's tinnitus was gathered. This included whether tinnitus was experienced in one ear (one-sided) or both ears (two-sided) and if it was constant or intermittent.

These responses were subsequently used to inform the composition of several electroacoustic miniatures of the *narrative form*, as defined by Chippewa (2014). The intention behind this was to allow these sounds to be shared with others, which may help those who do not experience tinnitus to appreciate the experience, and give a voice to participants in the study. Each miniature composition is described below.

2.1 *Radiophonic*

This piece was created in response to the following description, provided by a participant whose tinnitus was constant and in both ears:

> "My tinnitus sounds like static, similar to the noise found on old TV's (where you changed to a channel that wasn't live and got the black/white fuzz)."

The piece was extremely simple to create using a white noise generator to resemble the type of television 'static' noise encountered on analogue sets. Whilst the initial plan was to record a real sample of this noise directly from a television, it was problematic to find one that made this sound.

The noise altered slightly by modulating its amplitude of the sound subtlety over time, to avoid it sounding overly unnatural and to give the listener the sense of some direction of 'searching' taking place, such as when attempting to tune a television or radio to a specific channel.

2.2 *Sonorous Screaming*

This piece was created in response to the following description, provided by a participant whose tinnitus was constant and in one ear:

> "Ringing to a buzzing that can change pitch to a ringing like screaming."

This composition features multiple pure tones at high, often piercing frequencies. There are static tones over its duration, specifically at around 6.4 12.2 and 19.2 kHz. Alongside these, and more noticeable, is a tone that begins around 2 kHz, and rises to 3 kHz before gradually falling back to 2 kHz. This tone has multiple harmonics, most notably the 3rd and 4th,and has a rasping, stuttering texture.

Sine tone generation serves to provide the constant pitched tones in the background, which produce a constant whine and serve as a suitable bed for the other sounds. The climbing and descending tone, reflecting the change of pitch in the qualitative description, was created by modulating a

harmonically rich tone with a recording of a piece of machinery, before applying a noise gate and adding additional distortion.

2.3 *Fragmentary Modulation*

This piece was created in response to the following description, provided by a participant whose tinnitus was constant and in both ears:

> "I hear a constant hissing/white noise sound in both ears with a high pitched ringing. The ringing gets louder and quieter throughout the day and is louder or more prominent in my right ear. On top of this, I hear temporary low tones, incredibly high tones, machinery noises"

The base layer for this composition is white noise, in order to provide a quiet hiss, which serves as a reference level to the rest of the components. Seated on top of the noise is a ringing sound, which modulates heavily in terms of its amplitude, with a large dynamic range. This tone is centred around 2.2 kHz and cuts through starkly. It is complemented by other occasional, quieter, tones: one around 150 Hz and another at 4.4 kHz. Finally, there are two brief occurrences of a rattling. Although the piece is a stereo composition, it is biased by around 4 dB mean RMS to the right channel.

The work was created by using a white noise generator, with the screaming tone being the result of experimenting with microphonic feedback in the studio. By directing and moving a handheld microphone, it was possible to modulate and conduct the sound with the desired effect. Additional tones were added using a sine wave generator and the rattling was overlaid by using a time stretched recording of a piece of machinery.

2.4 *Buzz Burst*

This piece was created in response to the following description, provided by a participant whose tinnitus was intermittent and in one ear:

> "Low frequency buzzing, in left ear starts with short bursts close together, a bit like revving an engine, then turns into longer bursts of buzzing interspersed with more short bursts. Longer buzzes can go on for 2-10 seconds."

Created sometime after the preceding three, this composition takes a more structured and considered approach of relating the literature to on tinnitus to the qualitative data obtained. Specifically, this composition draws upon the experiments reported earlier of Eggermont and Roberts (2004) and replicates their findings of tinnitus noise being most prominent in lower frequency bands. As such, the majority of buzzing was created using square wave generators, with small amounts of modulation applied and a duty cycle of 40%.

A range of buzzing tones were created between 500 Hz and 4 kHz in 500 Hz intervals, where Eggermont and Roberts (2004) identified the greatest contributing frequency bands to perceptions of tinnitus. Using the game engine FMOD Studio, these sounds are selected using a probability distribution, where sound samples at lower frequencies are more likely to be chosen than those at high frequencies. This was supplemented by the performance, during recording, of a pitch shifting feature, to emulate the "*revving an engine*" element. Finally, the sound of an engine was added, alongside a 50 Hz square wave, to bring some weight to the piece. All sound elements were panned with a bias to one side (left stereo channel).

3. COMPOSITION: EFFECTS OF ALCOHOL ON HEARING

Whilst there is much hearsay, limited research exists on the immediate and short-term effects of alcohol consumption on the human auditory system. Early work by Pearson, Dawe and Timney (1999) investigated how the consumption of alcohol, specifically a Blood Alcohol Content (BAC) of 72 mg/dl, affected the ability of six participants to detect audible tones of varying frequency and intensity. Significant increases in the threshold of audibility due to alcohol consumption ranged from between 5 dB and 10 dB at 200 Hz, and just under 5 dB at 400 Hz for a monoaural source only. Generally, the trend was that the auditory impairment reduced as a function of increasing frequency.

A case study by Antonopoulos et al. (2012) reports upon sudden reduction in hearing ability in one individual who prior to their hearing loss undertook acute alcohol consumption coupled with the sniffing of heroin. The person was successfully treated and later had normal hearing function restored. Comparing the audiograms pre and post treatment demonstrates that impairments across both ears were, at least: ~10 dB reduction below 500 Hz; ~40 dB reduction at 2 kHz; and ~10 dB above 4 kHz.

Most notably, and influential in the electroacoustic work produced here, is the research reported by Upile et al. (2007). In their study, a total of 30 participants were recruited. Of the 26 who completed the full study, they had an average level of alcohol of 62 u/l of breath at the time of testing. In all participants, the ingestion of alcohol was shown to increase the threshold of hearing, with some frequencies having greater levels of impairment than others. Increases in alcohol

concentration in breath positively correlated with auditory impairment, suggesting that the more alcohol is consumed, the greater the impairment becomes. In men, auditory threshold at 250 Hz rose 6 dB and 12 dB in females. At 500 Hz it was 5 dB in males and 17 dB in females. However, the lowest impairments were seen at 2 kHz, where the impairment was 2 dB in males and 5 dB in females, with all data being shown in Figure 1.

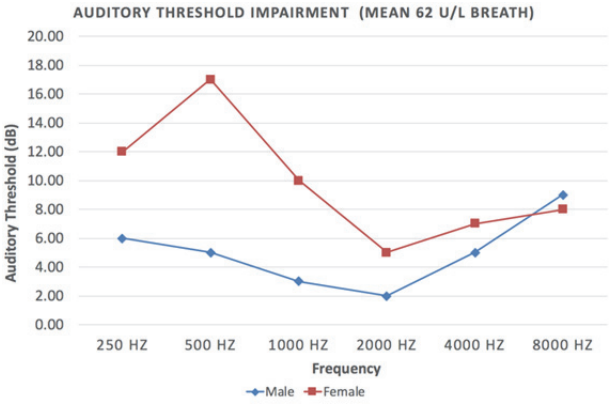

Figure 1: *Average auditory threshold impairments for males and females reported by Upile et al. (2007)*

Thus, the results obtained by Upile et al. (2007) are similar to those of Pearson, Dawe and Timney (1999) insomuch as they found that hearing impairment was greatest at lower frequencies.

3.1 *euphoria < dysphoria(Friday)*

This composition draws inspiration from the techniques of a sound walk, which typically involves the artist utilizing portable binaural recording equipment to record their journey through the various soundscapes and environments that they encounter along the way (Westerkamp 1974). Soundwalks are often used to provide recreations of the real-world soundscape (Schafer 1974, Semidor 2006, Adams et al. 2008) and can be a mechanism for narrative or creative practice (Black 2010, Paquette & McCartney 2012, Koutsomichalis 2013). Thus, the playback of these recordings provides listeners with a representation of the environment and is intended to allow them to experience the atmosphere and sonic landscape as though they are embodying the original listener.

This composition integrates findings of the study by Upile et al. (2007), gradually introducing filters, attenuation and distortion over the course of an abridged alcoholic binge drinking session that reflects the increasing impairment in auditory threshold. As shown in Figure 2, the dashed line shows the average value of the average impairments between males and females and was used to design the filter applied in the electroacoustic piece.

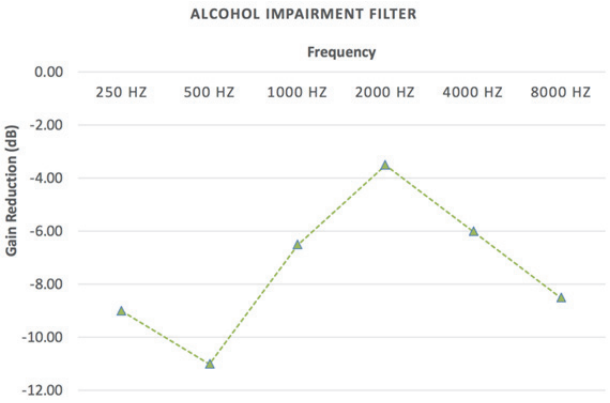

Figure 2: *Audio Impairment Filter based upon average impairments from the averages for males and females reported by Upile et al. (2007)*

The overriding intention of the piece, therefore, is to take the listener through a sonic narrative inspired by the notorious, and often dangerous, drinking culture reported in the UK (Szmigin et al. 2008). In particular, it adopts the typology of "*going out with friends*" as described by Ally et al. (2016).

This is achieved by the construction of a soundwalk following the typical events of an evening of drinking and socialising with friends. It is worth highlighting that the piece is not a true soundwalk, since it was composited, rather than recorded, hence it might be considered a *faux* soundwalk. The listener, presented as embodying the protagonist, is taken on a sonic journey involving stops at several nightspots, including bars, clubs, nightclubs, and eventually a hospital ward, created by field recordings of these environments or the recreation of these environments by compositing the required sounds. The narrative follows the demise of the protagonist as they drink more and more alcohol, becoming increasingly intoxicated, eventually vomiting, collapsing and regaining consciousness in hospital.

The notion of the soundwalk is reflected literally throughout, via the use of footsteps, recorded using Foley techniques, which are overlaid onto the soundscapes presented. To try and bring some task-association to the piece, each consumption of alcohol is marked by a spot sound, such as the opening of a bottle or the 'glug' of a drink being poured. Each of these epochs result in the impairment filter being increased in its intensity.

3.2 *euphoria > dysphoria(Sunday)*

Adopting a similar narrative and real-world style to *euphoria < dysphoria(Friday)*, this work steers way from an imitation soundwalk in favour of a soundscape (Schafer 1974). As with *euphoria < dysphoria(Friday)*, it aims to provide the listener with an embodied experience, so that they might be

inhabiting the environment presented sonically. The work makes use of the filter devised from the work of Upile et al. (2002), shown in Figure 2, and again has the intention of letting the listener experience the impairments to hearing that can occur through the consumption of alcohol.

In this composition, however, the narrative is different to that of *euphoria < dysphoria(Friday).* On this occasion, the piece was designed to relay the recovery of our embodied protagonist from a heavy drinking session. As they lay near a small river in a country park, listening to the sounds of the dawn chorus and the various birds and other wildlife around them, they gradually lift themselves out of their intoxicated state and arrive back to normality.

In this work, the filter is most heavily featured at the beginning, and is slowly removed over the duration. A deliberate intention was to employ a more static, but wide spectrum sound, so as to help the listener fully appreciate that the sounds around them are initially obstructed. As such, a source similar to white noise was desirable, and this was realised through a field recording of a small river. This was overlaid with additional recordings made of birds and insects, and further supplemented with other wildlife, which were pitch and amplitude modulated. Following the opposite structure to *euphoria < dysphoria(Friday),* the filter gradually lifts in response to epochs, this time being the noises made by the wildlife in the environment, before the filter is lifted completed.

4. DISCUSSION AND FUTURE WORK

The pieces composed in response to hearing impairments related to tinnitus and alcohol are successful in conveying a sense of what it is like for a person who is affected by each of the conditions, though there is scope and areas for enhancement.

4.1 Compositions on Tinnitus

With respect to the pieces created to represent experiences of tinnitus, these convey a strong aspect of discomfort, typically overwhelming the audio sense of the listener. A primary limitation of these is that they may frequently be too literal and there is a concern that the use of artistic license, particularly in the subjective interpretation of the qualitative accounts, in production may mean they are no longer true representations of the participant who expressed them.

This was a notable challenge in producing these works. Often, the compositions would initially sound quite simple or minimalist. In iterating each piece, additional elements, filters and effects would be added, but it was difficult to know how far to progress each piece because of a concern that it may no longer be true to the description given. However, without consulting the participant after the work was produced, it would be impossible to know if even the original version was accurate.

4.2 Compositions on Alcohol Impairment

In *euphoria < dysphoria(Friday)* the approach of the soundwalk was intended to gain the interest of the listener through its narrative structure and present them with a situation with which they can empathise. In terms of criticism, on reflection, the warning element of the piece (the protagonist appearing to be in hospital and subsequently dying) feels melodramatic. A technical limitation of the piece was that the filter, designed to reflect the hearing impairment, is often difficult to perceive, especially when first introduced meaning that the intention to highlight this impairment may not be clear.

The second piece, *euphoria > dysphoria(Sunday)* is a subtler work, in terms of the way it deals with the impairment filter. The work is much less dynamic, mainly through its composition as a soundscape, rather than soundwalk. Produced later, it does not try to over-emphasise the effect of the filter and the presence of the constant noise based sound source (the river) arguably does a better job of highlighting the changes as the filter is lifted. Although it is less direct and stark, in the sense of being a warning about the dangers of binge drinking, it does offer some hope of a return to clarity at its conclusion.

4.3 Areas for Future Exploration

An interesting avenue for further work, especially in the case of representations designed to communicate experiences of tinnitus, would be in the co-creation of electroacoustic pieces. This could be carried out in small workshops with people who live with tinnitus, placing greater emphasis on participants themselves composing sounds, or through a process of dialogue and iteration, with the artist responding to direction from participants.

As for expansions of the work around impairment due to alcohol consumption, one clear intention is to be able to re-use the soundwalk methodology but by capturing a true ‘first-person’ account using a binaural recording system. This set-up, which would require playback to listeners on a set of headphones, should help to immerse the listener more in the environment and by using headphones would allow them to better perceive changes to the frequency spectrum as the virtual alcohol is consumed and their hearing impaired as a consequence.

As with earlier work relating to altered states of consciousness, as a result of intoxication by use of drugs, the ability to represent auditory impairment may have wider reaching applications, such as in their representation in film, radio art, and computer games, such as has been recently suggested by Smucker (2018) regarding the representation of drunkenness in computer games. These media may be effective in communicating the underlying health issues effectively to a wide audience.

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