

How are the Psychoacoustic Theories of Spatialisation are used within Music Production

DISSERTATION (M6X01791)

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Introduction

This study is called “How are the Psychoacoustic Theories of Spatialisation are used within Music Production” but the question of this study is “How are the psychoacoustic theories of spatialisation used within music production?” This essay is going to explore the merging of both the theoretical and the practical sides of music production and Psychoacoustic Theories of Spatialisation. The word spatialisation refers to the contextualisation and the conceptual creation of sound within a physical, conceptual or virtual space, the word space meaning an environment in which a sound or sounds are localised (Baalman, 2010). The theories of Helmut Haas and Lothar Cremer are going to be explored along with the practical applications of these theories employed by practitioners such as Chris Lord-Alge and Sam Phillips within this essay. The structure and layout of this essay will first focus on the outlining of the terms; music production, perception and psychoacoustics. This is for a better understanding of the relations between psychoacoustics and music production practice. This will be followed by the main section of the essay which is split into the two psychoacoustic theories; early reflection and the Haas effect. This will finish with a conclusion. The early reflection and the Haas effect sections will be split up into the theoretical and the practical application of the theories. This essay will be beneficial in future due to personal aspirations of entering the field, music production and desiring to know more of this field due to currently studying music technology at the University of Wales Trinity St. David, which focuses on music production and the study of theoretical concepts employed by practitioners. This essay will explore how to theorise is used within the practice, specifically if theorists can influence the decisions of practitioners as inspired by Chris Lord-Alge his works within the field of music production.

Outlining terms

Music Production

The term music production is a broad term that will refer to the process of creating a musical composition for this essay. Usually, depending on the genre of music there are around seven different stages of the production process that can be consolidated into three main stages for simplicity (Music Production Guide, 2011). The three main stages are the composition process, the recording process and the mixing processes. They can be thought of the pre-production, mid-production and post-production processes (Whitney, 2017) (Henry, 2001) (BBC Music Introducing, 2018). The composition stage starts with the initial writing process of the song. This is followed by the demo which is the final artefact of the writing process that is formatted in a presentable way to approximate a musical concept (BBC Music Introducing, 2018). It would usually be during the demo phase where practice would occur if a band was creating a composition (Music Production Guide, 2011). Once the Demo has received a positive response, the recording phase occurs where the main bulk of the creative ideas

are able to be explored. This includes the basic tracking stage that usually sets in place the main building blocks of the composition depending on the genre of music. The overdubbing which is where specific solo instruments and vocals are usually recorded isolated from the rest of the track and are later layered onto of the track once the previous process is completed (Henry, 2001) (Amyes, 1990). The post-production processes come after, where the editing phase begins where the recorded tracks are cleaned up and arranged if necessary. This is followed by the mixing phase where the bulk of the post-production is taking place. The term 'mix' or 'mixing' is the post-production process of taking a multitrack session and 'mixing' it down to a single stereo track. The mastering phase follows once the mixing is completed where the final stereo track would be processed to standardise the audio, preparing it for radio play and for it to be played onto different mediums (Music Production Guide, 2011). The whole purpose of music production with its layers that accompanied it is to create a conceptual world of its own within a given composition, a world the artist or composer creates to create for an audience to experienced. The term 'soundscape' or 'sonic pellet' will be used to describe the conceptual artistic intentions for the sound of a composition.

Perception

In order for the discussion of music production linking with a psychoacoustic theory to be understood, the theoretical concepts of perception must be understood. Perception is a subject area covering a broad range of subjects. The focus of subject of perception will be on the contextualisation of the sensory information, specifically the auditory system (Weissman, 2011) (Akins, 1998). Psychoacoustic theories heavily rely on the comprehension of certain aspects of the theory of perception. This is due to the mechanics and building blocks of the theories of psychoacoustics (Deryagina & Khokhlova, 2015). The auditory system actively perceives to contextualise and comprehend the effects of psychoacoustic on such individual. These effects can be perceived consciously or subconsciously to an individual meaning an individual can be aware of what psychoacoustic effects are being experienced, but also an individual can also be unaware of what is being perceived yet still experience psychoacoustic effects (Deryagina & Khokhlova, 2015) (Weissman, 2011).

Music production relies on an individual to make active and conscious decisions regarding how a soundscape and music sounds and such skill requires a level of perception to take decisive action within the practice of music production (Hugill, 2008). Perception is achieved through actively Interpreting external sensory information, in conjunction with a conscious or subconscious decision referring to information through former experiences. The process of the interpretation of past experiences are created through every moment experienced, that in turn effects an individual's interpretation of current and future experiences (Sokolowski, 2008). Subconscious explanations are created through the information as a means of explaining the reality that surrounds an individual and

as a response to what is observed by an individual (Cowey, 2013) (Azzopardi & Evans, 2017). This suggests that individuals will have a perception of something which would be different to another individual, even when the origin of the source was constant (AGoodale & Humphrey, 1998). Active Interpretation that originates from a concept with value or meaning in the form of a belief or a perceived concept will affect the future perception of events (Giles, et al., 2016) (Faivre, et al., 2014). Perception then merges with the thought process and decision making of an individual and will affect interpretations and opinions in future (Krishna, 2011). There are many different theories and concepts that surround the different types of perception; many categories ranging from; neurological, sensory to social perception, with numerous other concepts and theories (Open Biological and Biomedical Ontologies, 2018). TThe focus of this reading will primarily look at the perception of sensory information specifically the auditory system which will relate to the ideas and the concept of psychoacoustics and the application of psychoacoustic theories within music production.

Psychoacoustics

The exploration of the concepts behind psychoacoustic theory focuses on the physics that occurs within an observer's environment, the interface between an individual and their surroundings and how the sound is then perceived (Plack, 2005). The study of Psychoacoustics at its core can be defined as the perception of sound. Within its a theory, the ideas can be broken down into two intertwining categories; the 'inner ear' and the 'auditory processing system.' The study of the 'inner ear' Explores how sound effects the 'inner ear' and how the ear processes sound into neural signals (Shirley's Preschool Activities, 2016). This subject touches upon on the anatomy of the of the sensory organs, but primarily attentive on the inner-ear or in other words, the study of the 'inner ear' focuses on the biological and anatomical aspect of psychoacoustics (Open Biological and Biomedical Ontologies, 2018). The study of the 'auditory processing system' looks at how the neural signals are turned into a form that the human mind can perceive and understand and the biological mechanics that go into understanding how it works and how the physical anatomy of the ear can change the perception of an external stimuli between individuals (Ballou, 2008) (Shirley's Preschool Activities, 2016). Psychoacoustics is the study of auditory perception and how the anatomy of the human auditory system influences the perception of occurring external sounds. This also Incorporating acoustical engineering to help explain how an external stimulus can affect an individual internally, in turn, has an influence on an individual psychologically (Ballou, 2008). Theorists suggest that the explanation of the complexity of the auditory system is due to the assistance of human survival from an 'evolutionary' standpoint (Hiroshi, et al., 2006).

Early reflection

Theory

A theorist of the perception of sound within spatial audio thus exploring certain psychoacoustic concepts through works is Lothar Cremer (1905-1990), a respected German acoustical and electrical engineer who worked within the field of physics, architecture and design of acoustic space (Cremer, 1948) (Cremer, 1984). Through the design of theatres and concert halls the discovery of a then psychoacoustical phenomenon now known as 'early reflection' theory or 'law of the first wave-front' was made (Cremer, 1982). This relates to how the ears and brain can interpret information about a space or environment and the direction of a sound source without any pre-knowledge of the situation or external to inform but from the ears (X.Hüg, et al., 2014) (Open Biological and Biomedical Ontologies, 2018).

The understanding of basic spatialisation and the components that make up spatialisation needs to be understood to assist in contextualising these theories. As previously stated in the introduction, the word spatialisation or spatialise, referring to the conceptual creation and the contextualisation the of sound within a physical, conceptual or virtual space. The word space will be used to describe an environment in which a sound or sounds are localised (Baalman, 2010). When a sound leaves a source, whether it is from an instrument or speaker, the sound travels in the direction that the source of sound is facing, so this means that if an observer was facing the source, sound waves would travel directly to the ears of the observer unaffected (Cremer, 1982). This will be called the direct sound, in technical terms the 'direct signal' and 'the initial attack' in practical terms (Haas, 1972) (Cremer, 1982). This will then be followed by a pre-delay where there is an undefined moment of time delay before the 'early reflections' of the sound signal would then reach the observer (Baalman, 2010). These reflections are from nearby reflective surfaces where the sound would be altered in frequency response and phasing

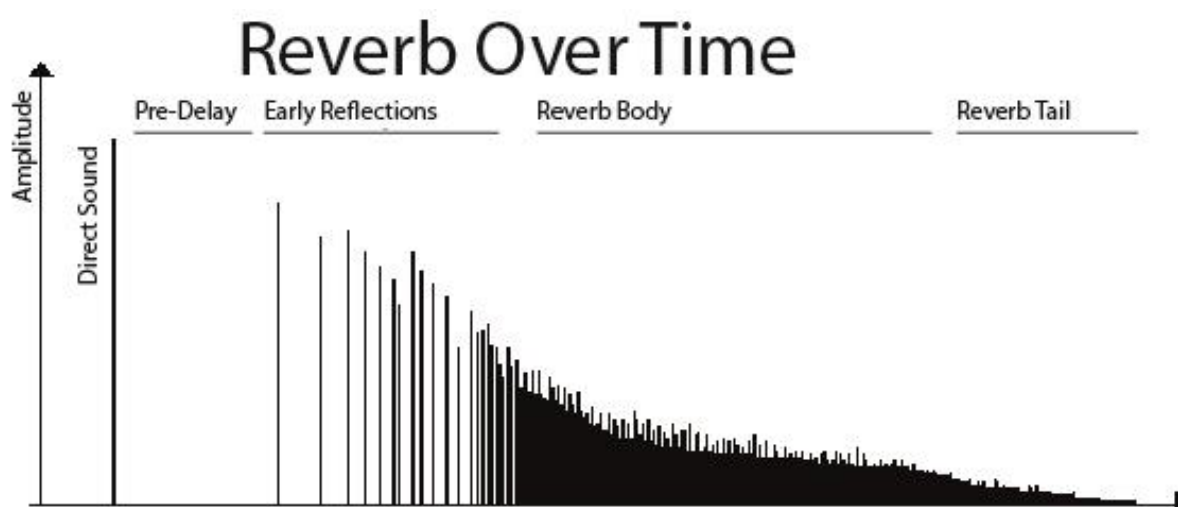


Figure 1; A diagram illustrating reverb over time (Burel, 2008)

due to the differences between distances (Cremer, 1948). The reverb body or the late reflections are followed, which are many different reflections bouncing off each other and 'defuse' the sound. This is what causes reverb to carry a sound, to sustain a sound for a duration of time also known as the 'diffusion' (Türköz, 2016). As Lothar Cremer states in his book *Principles and applications of room acoustics* "Diffusion is a consequence of the reflections on the room surfaces not being specular (i.e. mirror-like), but rather scattered in various directions" (Cremer, 1982). This is then followed by the 'tail' of the reverb or 'reverb tail' which is the remanence of the original sound signal but would have lost all its energy through the different surfaces within the space (Woodhouse, 1993).

The first to explore the concept of early reflection theory was Cremer, but Hans Wallach (1904-1998) is identified for the contribution that was offered to the research regarding the theory of early reflection theory. The psychoacoustic effect was named by Helmut Haas in his PhD thesis 'The Influence of a Single Echo on the Audibility of Speech' in 1949 along with the discovery of the *Precedence effect* which will be discussed later within this essay (Haas, 1949). The paper focuses on the theories of Cremer and their effects on language and speech but for this essay will focus on is psychoacoustic properties and how they can be used within a music production.

Another case study that focuses on the theories of Lothar Cremer is called "On the Playability of Violins, Part I: Reflection Function" by a Cambridge University Engineering Professor, Jim Woodhouse (Woodhouse, 1993). This study explores how the shape of a room and the reflection of the surfaces of the room affects both the sound of an instrument within a space and the perception of that sound by an individual. Specifically, the sound of a violin and its effects on violin players and how space affects their perception, that in turn affects their judgement when making real-time decisions when playing the violin. Even though this case study focuses its effects on musicians, this could be applied to any individual despite the fact that this study was created to assist the creation of concert spaces (Woodhouse, 1993).

The experiments of Haas were set up so that the early reflections can be isolated from the reverb body and tail. The conclusion of this study on the theories of early reflection was that; the direct sound and early reflection were perceived as one sound as opposed to the two separate components of the sound depending on the pre-delay (Haas, 1949). In order for the merging of the two separate components to take place, the early reflections must be heard less than 5ms for a short direct sound which is typically a click and less than 40ms for complex sounds such as piano, violin or speech after the original signal and was less than 10dB than the original sound source in a controlled environment (Cremer, 1948) (Haas, 1949). If the *early reflections* were 15dB louder than the direct sound, the auditory system would no longer be able to contextualise and therefore would not have the ability to

perceive the sound as being situated in space (Haas, 1949) (Haas, 1972). Anything above 40ms would be perceived as a defused reflection and two separate sounds and would have a 'Slapping' effect. In technical terminology, this would be known as 'slap-back delay,' but this will be discussed further into this section of this essay (Blitz, 2016). Haas also stated that “the longer the delay, the larger perceived space” Which means that the delay determines the size of perceived space. (Haas, 1949)

Diagram of Early Reflection

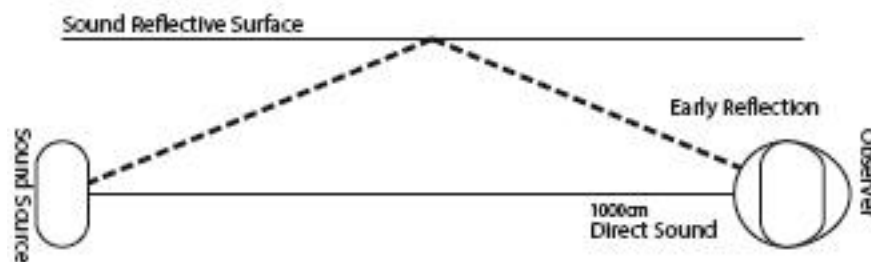


Figure 2; This is a diagram of the mechanics of Early Reflection (Newell, 2006)

The conclusion of Helmut Haas and Hans Wallach theories suggested that the direction of the sound origin could be preserved if in an isolated space with no reflective surfaces, but due to subtle variants with phasing caused by time delays in relation to reflections on surfaces and added distances because of these reflections, creates a stereo image of the space in which the sound originates in (Blauert, 1983). Due to the binaural nature of this effect within three-dimensional space, the direction in which a sound source could be determined by listening without prior knowledge of the direction of the sound (Cremer, 1982) (Woodhouse, 1993). This is due to; the differences in amplitude of the sound in each ear, the differences in phasing due to the different distances between each ear and by the early reflections from the space in which the observer is situated in (Woodhouse, 1993). This psychoacoustic effect is called the *Haas effect* or the *Precedence effect*; but binaural nature of this aspect of 'early reflection' theory will be discussed further on into this essay (Haas, 1949). In all, information that the brain receives can then be processed, which is how a sound can be perceived as artificial if taken out of the context of the space which has no reflections on it due to the lack of contextualisation of information.

The conclusion of Jim Woodhouse case study backs up the conclusion of Helmut Haas but also adds to the conclusion. The additional conclusion discusses that though information about space is carried through the early reflections and the different delay times between the individual components that make up the early reflection. Information is also carried through differences in frequency response between the direct sound and the early reflection (Woodhouse, 1993). This is effecting the way that the space sound waves respond to the shape of the space and even the materials that space is made from. Jim Woodhouse discusses that it is due to the perception of the differences in the direct and the

‘early reflection’ that the ability to determine the composition of the materials of a reflective surface (Woodhouse, 1993). For example, if the composition of a reflective surface is made from wool, it would be perceived as a ‘muffled’ reflection even without prior knowledge of what the composition of the surface. Same for other surfaces, if the composition of a surface was constructed from concrete, an observer would perceive the reflective response as ‘bright’ and the individual would be able to determine the surface was made of a hard material. Basically, the auditory system uses the theories of early reflection to determine the size of the environment in which an observer is in, and what texture or materials the reflective surface is made from within that given environment. As stated by Cremer “Diffusion is a consequence of the reflections on the room surfaces not being specular (i.e. mirror-like), but rather scattered in various directions” (Cremer, 1982).

Practical application

Within the practice of music production, ‘early reflections’ isolated from the reverb body and tail with a pre-delay more than 40ms is commonly referred as ‘slap-back delay,’ depending on the different timings of the individual components that make up the early reflection (Pro Sound News, 2006) (Slaten, 2011) (Stewart, 1999). An isolated space is needed while recording to obtain full control of a sound or instrument within a mix (Owsinski, 2014) (Newell, 2006). Adding the reverb artificially might be necessary to contextualise the sound depending on the creative objective of the composition.

By having a sound that is isolated, it can sound artificial due to the lack of information on the space given by early reflections. The uses of slap-back delay within music production are to contextualise isolated instruments within a space (Owsinski, 2014) (White, 2003). The word room will be used to both describe a recording studio but also be used to describe the reflective tonal characteristics of the early reflections and decay of those reflections.



Figure 3; Isolated recording booth used to remove room noise and room reverb (Editors Keys, 2018)

During the mid to late 50s, four-track recording devices were created due to the rise of the popularity of vinyl along with rock and roll, which introduced creative opportunities for recording such as multi-track recording takes, which means to record with multiple tracks at once, or post tracking, which means to recording something alongside a track after an existing take (All Music, 2009) (Rumsey & McCormick, 2014). This meant that a band didn’t need to be recorded all at the same time and that the vocals, for instance could be recorded in their own with better isolation of other instruments and of the reflective sound of the room (Rumsey & McCormick, 2014).

The sound of the room would benefit instruments by contextualising the sound and by giving the perception of the sound to be more natural which could be considered a problem with isolating tracks (Amyes, 1990). A practitioner who came up with a solution to this problem was Sam Phillips who was most notably known as the engineer that worked with Elvis Presley (Larkin, 2006). Sam Phillips came up with a way of creating a sound of a room in post-production without using expensive studio space by using a tape machine with multiple tracks and using delay that occurs when feeding the signal from

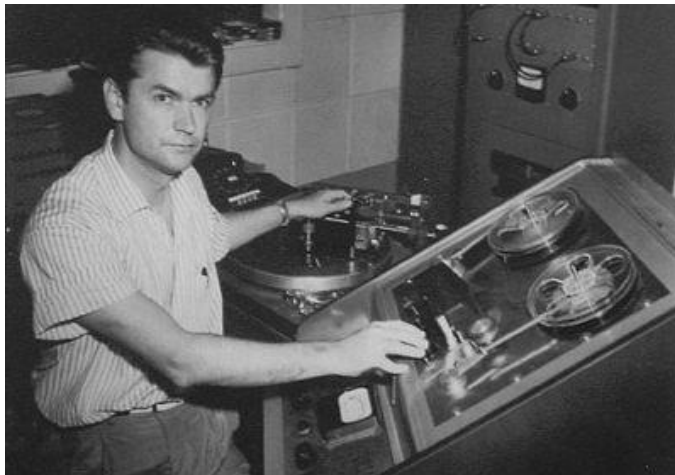


Figure 4; This is Sam Phillips in the studio using a tape machine, the same machine that recorded and created the Tape-Delay on "Blue Moon of Kentucky" by Elvis Presley (Unterberger, 2018)

one track recorded onto another due to the distances between the play and record head of the tape machine (Rumsey & McCormick, 2014). One of the first instances of this effect can be heard in the song "Blue Moon of Kentucky" by Elvis Presley (Blitz, 2016) (Presley, 1954).

Research suggests that Sam Phillips was

the practitioner that discovered the practical application of slap-back delay but there are many speculations on who created this effect first. Some state that this was the work of George Martin who produced the Beatles recordings in the 60s, whereas others say it was as early as Sam Phillips who recorded Elvis Presley in the mid to late 50s (Blitz, 2016) (Vince & Rouse, 1982) (Martin & Pearson, 1994). The findings of Sam Phillips reflect the theories of Lothar Cremer and then later explored by Helmut Haas even though Sam Phillips doesn't mention anything about Lothar Cremer theories.

Tape-based delay is still used to this day, but due to advances in technology, tape delays can be emulated along with reverbs and many other similar 'time domain effects.' An example of this is by looking at modern day practitioner Chris Lord-Alge, who is a Mixing engineer for productions, bands and artists such as; Green Day, Muse, The Greatest Showman, Foo Fighters, Keith Urban and Michael Bublé (All Music, 2018). Chris Lord-Alge is most notably known for his creative uses of reverbs and the practical theories that he uses within his practice (Lord-Alge, 2017) (Lord-Alge, 2018). Chris Lord-Alge stated in an interview that "to get a larger sound, you need to turn up the pre-delay on the reverb to be over 150ms rather than your usual 40ms" (Lord-Alge, 2017). Early reflection can be considered a key component for assisting the creation of a realistic sound-pallet or soundscape within a musical context. It is a crucial element for creating realistic reverb and even when isolated from the reverb body and tail, creating a slap-back delay effect, can be used creatively to add spatial context for

instruments and vocals within a mix. The evidence suggests that the reason why slap-back delay can give context to the soundscape is due to the psychoacoustic properties that it has upon an individual, conveying contextual information creating the illusion that the music is situated within a space that can be contextualised. Slap-back delay evidently uses the theory of early reflections, but through the research of the practitioners, there is no mention of any of the theorist and of their theories specifically. From what was gathered, however, the practitioners had a vague understanding of how the theory behind the concept of slap-back delay works and put the theory into practice.



Figure 5; This is the Waves H-Verb plug-in used to digitally recreate reverb and slap-back delay (Waves , 2018)

Theory

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Practical application

Common terms and concepts with regards to music production must be understood in order to understand the binaural Haas effect and its uses in practice. The term ‘panning’ or to ‘pan’ derives from the term panoramic but usually refers; the distribution of a monophonic audio channel to a stereo channel or multi-channel sound plane usually with the assistance of a ‘Pan-Pot’ or more formally known as a ‘Panoramic-Potentiometer.’ The way in which it does this is by changing the volumes of either the left or right channel (Hodgson, 2010) (Huber, 2017). Panning in the context of music production is essential because it is a way of separating instruments from one another in a mix, giving a form of directionality to specific sounds and is the start of creating a conceptual space (Hugill, 2008). For example; a piano and a harp are two different instruments, but they share the same frequency range, frequency range referring to the different components that make up the whole sound. If two instruments have the same frequency range as each other, the listener could have problems distinguishing each instance both instruments could get “lost in the mix.” There are a few ways to combat this, such as the use of equalisation, but probably the best solution for this problem is to pan each instrument within the stereo field (Weiss, 2011). However, this way of giving directionality in a mix is artificial, in the sense that the auditory system does not perceive sound the way that Panoramic-Potentiometers work, directionality comes from the many variants of the Haas effect as opposed to the amplitude difference in each ear alone (Weiss, 2011).

One alternative way of giving directionality in music production is by using the Haas effect its self, and there are a few different ways in which this could be implemented. The most common way is by using binaural microphones. It is a stereo microphone, usually built in the shape of a head with silicon ears and the reason why the microphone is shaped in such way it so emulates the human hearing and to capture sounds as close to how humans hear the sound (Nusser, 2014). The binaural microphone concept was created in 1881 as a novelty item used to listen to operas remotely. The binaural setup consisted of an array of carbon telephone microphones which was installed end to end of the *Opera Garnier* where the signals were transmitted from the microphone array to a specially designed headset with multiple speakers on to recreate the effects of being in the performance (Nusser, 2014). The popularity of this device dwindled, but in 1978, the first commercial binaural records were released by Lou Reed who was an experimental rock artist (Beech, 2013). The binaural technology started to gain popularity and now binaural microphones are now commercially available (Kelly, 2016). The reason why this effect can seem “weird” is because the binaural playback is giving information about an environment that is contradictory to the environment that the listener is in, leading the brain to become confused due to the contradictory contextualisation of the information. In other words, the mind cannot figure out where it’s location within that situation. Some individuals find this

experience unpleasant while others find it pleasurable (Beck, 2013). This can be experienced by listening to an *AMSR* Recording or formerly known as *Autonomous Sensory Meridian Response* Recording (Simner, et al., 2006). The most notable use of this microphone is for capturing orchestra



Figure 7; A KU 100 Neumann Binaural stereo microphone (Neumann, 2018)

head (Barratt & Davis, 2015). This is because an orchestra must be considered an experience, a binaural microphone is probably one of the best ways to capture both the space in which the orchestra is situated in and the directionality of each instrument (Shostakovich, 2013). These productions would still use traditional panning techniques because these methods of production work better within the context of a mix (The Making of 'The Incredibles', 2005).

An alternative method of using binaural effects within a music production is by using an effect called a stereo widener. It's predominantly used to transform a monophonic signal into a stereophonic signal with a perceived width (Thornton, 2010). Stereo widening is created by creating a copy of the mono signal and panning both audio signals to the left and right channel. One of the signals is then delayed by 20ms to 40ms utilising the theories of Haas to create a perceived 'wide' sound. This technique can also micro tune both signals up and down from each other by about -4 cent for the left channel and +4 cent for the right channel to create an even 'wider' sound (Sound Bridge, 2018). Cent is a unit of measurement used within pitching and tuning (Hyper Physics, 2008). This effect was most predominantly used within the late '70s to early '90s where it's most common uses are on instruments such as guitars and synthesizers for its widening capabilities and its abilities to create depth from a mono track without the use of reverb (Houghton, 2015) (d'Ark, 2017). An example of this effect being used within a composition during this time period is the band Toto song 'Rosanna,' where it can be heard on all the some of the rhythmic guitar tracks, all or the lead tracks and on the synthesizer solo (Toto, 1982). The effect is still used to this day in modern production as presented by Chris Lord-Alge during a short interview with 'Mixing with the Masters' showing the processing that went into a lead guitar track (Lord-Alge, 2017).

These are the ways in which the Haas effect can be used to create a binaural effect artificially. Authoritative directionality can be given within a music production without using traditional panning techniques. The research suggests that these binaural effects being used within the practice are usually used to create a bed for a sonic soundscape and pallet, usually in the form of either a room or ambient microphone for the binaural microphones or to give directionality to a specific instrument within a larger production. These productions would still use traditional panning techniques because these methods of production work better within the context of a mix. Also, the Haas effect can be used to combat directional masking, where one sound obscures the perceived direction of another or in other words focal panning or to draw the listener into the specific instrument. On the other hand, a problem that is associated with using this the binaural microphone is that it must be listened to on headphones for the effects to work due to the nature of the mechanics of the binaural effects. If listened through loudspeakers, audio from one speaker would be heard through the opposite ear, and the illusion would be broken. Other problems associated with using these theories within a music production, if only the Haas effect was used to give directionality, the perceived loudness would increase due to every instrument being played through both channels due to the way that the Haas effects mechanics. Also, comb filtering would occur due to the sum of the left and right channel causing phasing due to the mechanics of the Haas effect if the recording was to be played back in mono for radio play (Russell, 2010). These problems can be minimised and unnoticeable in most cases of well-produced music if these effects binaural are used moderately.

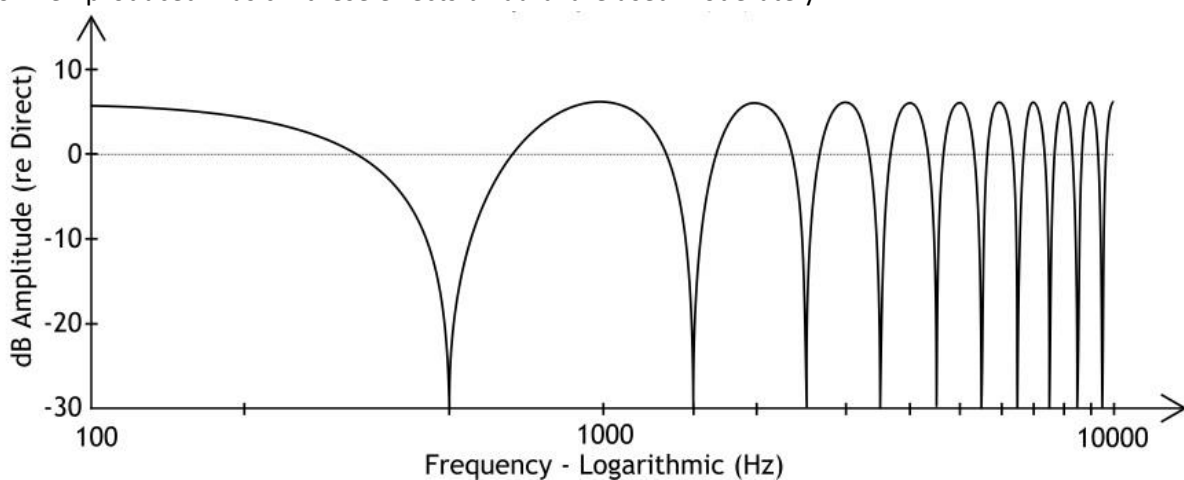


Figure 8; This diagram demonstrates the effects of comb-filtering induced by phasing (White, 2013)

Conclusion

The question “How are the psychoacoustic theories of spatialisation used within music production?” is answered through this essay through the discussion of and the exploration of two major psychoacoustic theories regarding spatialisation; early reflection theory and the Haas effect. A better understanding of the subjects and terminology arose through the outlining and analysis of the terms; music production, perception and psychoacoustics. A better understanding of the relations between psychoacoustics and music production practice was made through the analysis of the terms. As previously discussed with regards to early reflection, early reflection theory assisted in the creation of slap-back delay and in turn assisted in the creation of a realistic sound-pallet or soundscape within a musical context for the late '50s where the effect was most predominantly used. To this day this effect can still be used as shown by Chris Lord-Alge and his works. Early reflection is a vital component for producing an accurate sounding reverb. Slap-back delay can be utilised in a creative manner to enhance spatial context for sounds in relation to music production, presented through the works of both Chris Lord-Alge and Sam Phillips who produced Elvis Presley (Lord-Alge, 2017) (Lord-Alge, 2017) (Lord-Alge, 2018) (Presley, 1954). The information gathered through this investigation is extremely useful and applicable to music production. The theories and practices that were discussed were personally, foreign concepts before this essay but now, these concepts will be used in future endeavours and in personal music productions. Concepts such as the Slap-back effect being used to create a conceptual space and that the pre-delay determines the size of the conceptual space. The use of the Haas effect will also be used in future through the research presented. Using binaural techniques alongside traditional panning techniques to create authoritative directionality within a music production. Also, these techniques can be used in the creation process to give directionality to a specific instrument within a music production or to create a conceptual sonic soundscape and sound pallet using binaural microphones to capture an environment, usually in the form of a room or ambient microphone. A minor problem found with using the theories of Haas within music production is phasing that could affect a piece of music during playback if played in mono. This is most prevalent when listening to the effects of stereo widening. However, this problem rarely affects the outcome of the final production. A partial understanding of stereo widening was known before this essay but due to this research conveyed and improved comprehension of the theoretical concepts behind the effect can now lead to better-informed decisions within the personal practice and what to keep in mind about problems associated with using these effects.

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