

Creative music Production, Professional project  
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Why mono matters  
And how mono incompatibility can be used creatively.

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## **Introduction**

This thesis researches the questions, “How does mono incompatibility affect how consumers hear music?” and “How can mono incompatibility be used as a creative tool in composition?” The accompanying artefact will investigate the impact that summing a multi channel mix of music down to a mono output can have on the content of the final audio file. Factors to consider include phase cancellation of the left and right sides of the original stereo mix, which can cause a drastic drop in volume or complete cancellation when summed to mono and frequency masking. As frequency masking can be avoided through panning in a stereo file, the amount of masking may increase when summed to mono, however if elements that contribute to masking are removed through phase cancellation when summed to mono, it can be used to reveal content that wasn't heard when played in stereo.. This project aims to make use of these two compatibility issues as a creative tool through complete phase cancellation of elements in the mono sum and obfuscation of masked elements that get revealed after the phase cancellation takes place. This in theory could allow a mono version of an audio file to have drastically different content from the same file when listened to in stereo. The project will also investigate the use of listening devices used by music consumers and if they device they use to listen is mono or stereo.

## Literature Review

### Phase, cancellation, and mono compatibility.

The article *What is phase in audio? 5 ways to address phase issues* By Nick Messite

Describes that phase is the position of a signal within a single cycle of a waveform. This is typically measured using a sine wave as the simplest example. Phase positioning is measured in degrees with a waveform starting at 0°, rising to its peak at 90°, falling to the same level as zero again at 180°, falling to its lowest point at 270° and finally returning to 0° where the cycle of the waveform begins again.<sup>1</sup> The range of the highest and lowest point are dependant on the amplitude of the signal and the length of the waveform depends on the frequency.

Phase cancellation occurs when two signals with similar or identical frequency content are combined but the two signals have differing points in the positioning of their waveform. When applied subtly this has been used to achieve a “widening effect” in stereo mixes (1).

However in more extreme cases of phase cancellation the volume of the combined signal can decrease significantly or in the case of a mono output the signal can disappear completely at a 180° phase difference. If multiple correlated signals are played at the same time with the same phases positioning, the resulting signal will increase in volume and no frequency information will be lost.

*COMPATIBILITY PROBLEMS IN TWO-CHANNEL STEREOPHONIC RECORDINGS* by F. K. Harvey at the Audio engineering society conference 1961, discusses these issues extensively as at the time stereophonic signal was beginning to be used in FM broadcast. This conference paper is highly relevant to the project as it outlines methods through which phase cancellation and mono incompatibility is achieved and how it can affect a mono listeners experience with regard to balance, filtering and lost content from the stereo source.<sup>2</sup> It also describes how to observe phase

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<sup>1</sup> Messite, Nick, *What is phase in audio? 5 ways to address phase issues*. 28 October 2024

<sup>2</sup> F.K Harvey, Euke Edward, “*Compatibility problems in two-channel stereophonic recordings*” Audio engineering society 13th annual meeting, 1961

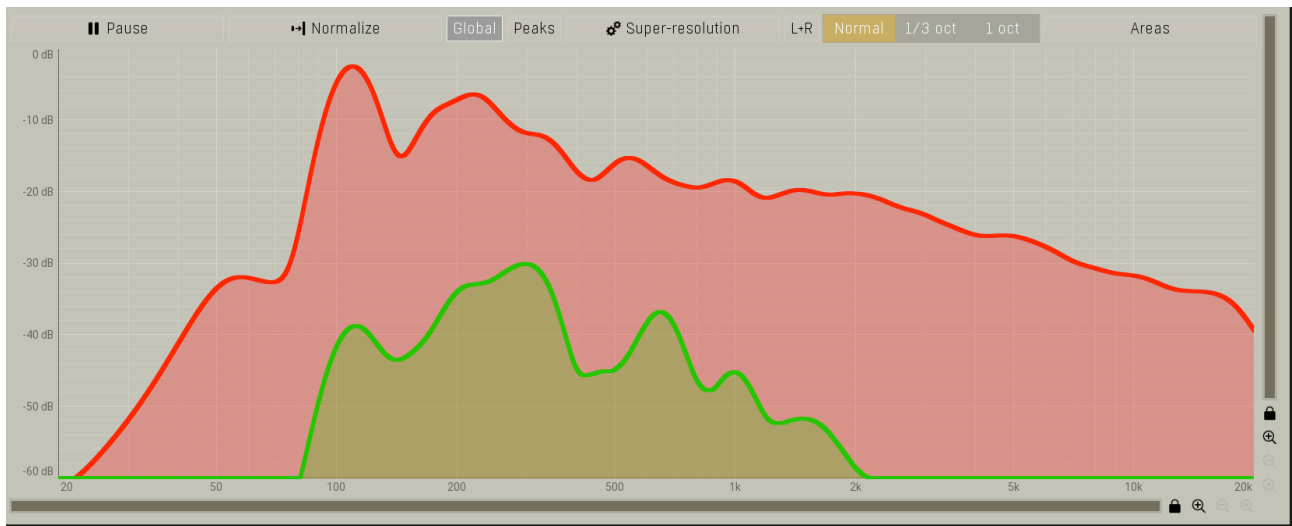
visually through the use of an oscilloscope whilst Mezzite offers a more modern approach to measuring phase cancellation with a goniometer such as ozone imager.<sup>3</sup>

The book *acoustics and psychoacoustics 4th edition* by David M. Howard and Jamie A. S Angus offers information on many of the topics relevant to this project such as chapter 1.3 “Adding sounds together” which discusses how signals interact with each other in the case of correlated(28) and uncorrelated sounds<sup>4</sup>(30) and chapter 1.6.3 “the effect of phase”.This directly relates to the phase cancellation that is central to this projects methodology.

### **Defining and quantifying masking**

Chapter 5.5.2 “Masking of on sound by another” also directly relates to the project as the project artefact aims to make use of masking in the stereo files. This chapter breaks down the interaction between between two masking signals as “Masker” and “Maskee” and how the volume relation between these two signals affects the threshold for a listener to perceive the “Maskee” signal depending on the volume difference between the two<sup>5</sup>. (262)

***“Masker” in red , “Maskee” in green.***<sup>6</sup>



<sup>3</sup> Ozone Imager [https://www.izotope.com/en/products/ozone-imager?srsltid=AfmBOoqZal7uRhXPnG2jlxt\\_YtCu\\_yjl16WkRrk4DU7jDeelk9fg4Mei](https://www.izotope.com/en/products/ozone-imager?srsltid=AfmBOoqZal7uRhXPnG2jlxt_YtCu_yjl16WkRrk4DU7jDeelk9fg4Mei)

<sup>4</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

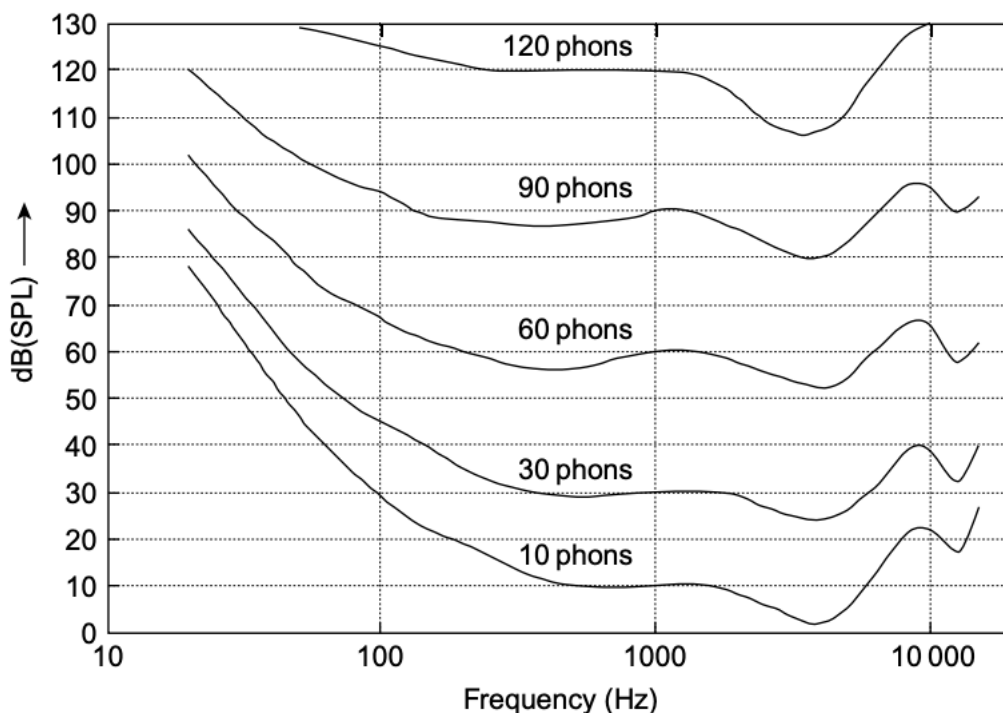
<sup>5</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

<sup>6</sup> Melda MultiAnalyser Plugin

Chapter 2.2 “Critical bands” explains how the human ear, in particular the basilar membrane perceives different frequency ranges through critical bands. The book compares the critical bands to a series of overlapping bandpass filters.(88). In the following chapter 2.3 “Frequency and pressure sensitivity ranges” the authors state that the range for human hearing is 20-20,000hz and how with age and hearing loss the range is reduced particularly in the higher frequencies.(89)<sup>7</sup>. This could impact how different listeners perceive masking as they may not have the hearing sensitivity to differentiate elements if they are experiencing hearing loss.

Chapter 2. 4 “loudness perception” outlines the concept of “equal loudness contours”. These contours offer a visual representation of the ratio between measured sound level and perceived loudness at different frequency’s.

**Fig2.12 from Acoustics and Psychoacoustics<sup>8</sup> (pg 93)**



<sup>7</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

<sup>8</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

This chart shows that the perceived loudness of differing frequencies( measured in phons) varies depending on the measured sound pressure level of the source audio. This will relate to how masking could be perceived differently at lower or higher listening levels as certain frequencies may be more or less audible to the human ear.

The AES convention paper *Quantitative Analysis of Masking in Multitrack Mixes using Loudness Loss* by Gordon Wichern, Hannah Robertson, and Aaron S. Wishnick analyses several mixes containing masked elements and measures the impact masking has on the overall volume of the track and how it affects instruments individually. It is also mentioned in chapter 3.1 that the results of this study were specifically limited to mono sums.<sup>9</sup> (4).

This paper also led to another source in its bibliography which was the AES convention paper *Describing the transparency of mixdowns: The Masked-to-Unmasked-Ratio* by Philipp Aichinger , Alois Sontacchi and Berit Schneider-Stickler.

This paper compares the ratio of the partial loudness of mixed instruments compared to the instruments in isolation (2). One of the key findings of this paper was that a masked to unmasked difference of 10% or lower in loudness level of an individual instrument was critical in professional sounding mixes to avoid obfuscation.<sup>10</sup> This is measured through analysing the loudness level of certain frequencies added by the instruments in the mix in comparison to those instruments in isolation .<sup>11</sup> It also states that a method for reduction of masking is to identify the most prominent frequency of each instrument and attenuate the other elements in that range, also known as “mirrored equalisation”. As this project aims to deliberately mask elements, applying the opposite of the guidance recommended here should yield higher results of masking.

The AES convention paper *An investigation into the efficacy of methods commonly employed by mix engineers to reduce frequency masking in the mixing of multitrack musical recordings* by Jonathan

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<sup>9</sup> Wichern, Gordon; Robertson, Hannah; Wishnick, Aaron, “*Quantitative Analysis of Masking in Multitrack Mixes Using Loudness Loss*”

<sup>10</sup> Aichinger, Philipp; Sontacchi, Alois; Schneider-Stickler, Berit, “*Describing the Transparency of Mixdowns: The Masked-to-Unmasked-Ratio*”

<sup>11</sup> Aichinger, Philipp; Sontacchi, Alois; Schneider-Stickler, Berit, “*Describing the Transparency of Mixdowns: The Masked-to-Unmasked-Ratio*”

P. Wakefield and Christopher Dewey discusses 3 common techniques used to reduce masking in a mix and their effectiveness. The 3 techniques are “Mirrored equalisation” as previously mentioned, “Frequency spectrum sharing” which involves low-pass filtering one instrument and high-pass filtering another, and “stereo panning” spreading masked elements across the stereo field. This paper also features tables showing which instruments masked each other at specific frequency’s and how the filters were applied.<sup>12</sup>(3) This will be highly informative for the deliberate masking of the project if the effective methods outlined here are utilised in the opposite manner.

### **User listening devices.**

*Listen up Ireland 2024* from IAB Ireland is a series of surveys and questionnaires sent out to the general public of Ireland on the consumption of digital audio. This included what digital devices people use for listening to audio and how it has changed over recent years. The reason this source is relevant to the project is because the device someone listens to audio on is entirely responsible for whether or not they are listening to a stereo or mono version. As this project aims to create a substantial difference between the files when listened to in mono and stereo, the listening device that is used is imperative. It also proves the importance of mono compatibility in a modern context as certain listening devices make use of mono output such as mobile phones and the lower end *Amazon echo* and *google home mini* smart speakers that have 1 speaker and therefore a mono output.<sup>13 14</sup>

The bar charts on slide 18 show a rise in the use of smart speakers to listen to audio from 2019 to 2024 with 29% of users in 2024 saying that they regularly use smart speakers to listen to audio and 15% claiming that it is their most used listening device.<sup>15</sup>This survey also shows that mobile phones

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<sup>12</sup> Wakefield, Jonathan; Dewey, Christopher “*An investigation into the efficacy of methods commonly employed by mix engineers to reduce frequency masking in the mixing of multitrack musical recordings*”

<sup>13</sup> Google Nest and Home device specifications <https://support.google.com/googlenest/answer/7072284?hl=en#zippy=%2Cgoogle-home-mini-st-gen>

<sup>14</sup> Amazon echo device specifications <https://www.amazon.co.uk/b?node=14100223031#503>

<sup>15</sup> IAB Ireland, “*Listen up Ireland 2024*”

are the most popular device for listening to digital audio but it does not clarify if it means the mobile device is used as the audio output or if it is connected to an external device such as headphones or a speaker. While these figures indicate that mono output is still relevant in the modern day, this will be further reinforced in a survey on listening habits conducted during the project.

### **How mono incompatibility can be used creatively**

In the video *DOOM: Behind the Music* from the GDC festival of gaming Youtube channel, Mick Gordon, the composer for the video game “DOOM 2016” describes his use of mono compatibility to hide subliminal messages at 42:17. He achieves this through the same techniques of phase cancellation and masking previously described in this literature review. This is done by duplicating a signal, flipping the polarity of one of the duplicates and therefore creating 180° phase cancellation and panning them hard left and right. This results in the signal being heard when listened to in stereo but disappearing completely in a mono sum due to the complete phase cancellation. This signal that is removed in mono was originally masking a hidden sound buried underneath that can only be noticed after the mono phase cancellation. <sup>16</sup>This is a highly relevant source as it utilises the exact same techniques that the artefact of the project aims to make use of in a musical context to create differences between the stereo and mono versions of the same file.

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<sup>16</sup> Gordon, Mick, “DOOM: Behind the Music”, Youtube, uploaded by GDC Festival of Gaming Aug 22, 2017.

## Methodology

### The pieces created and their goals.

Throughout this project three pieces of music were created, each aiming to make use of phase cancellation when summed to mono to achieve different effects.

The first piece aims to swap the genre of music heard when listening in stereo or mono. In this case a loud rock song can be heard in stereo and a gentle folk song can be heard when listening in mono. The rock song consists of distorted electric guitars and bass as well as drums while the folk song consists of acoustic guitars and a banjo. These two genres were chosen as they have somewhat similar instrumentation, however the added harmonics from the distortion of the electric guitars allow the frequency content to have a wider range for masking the folk song hiding underneath. The overhead cymbals of the drum kit also assisted in masking the high frequencies.

The second piece of music aims to shift the instrumentation from a full orchestra in stereo to a single piano in mono. This effectively creates a built in piano reduction of the orchestral arrangement. The orchestral elements include strings, woodwinds, brass and timpani. The combination of all of these instrument sections sufficiently covers the spectral range of the piano for masking the mono version.

The third piece of music created aims to hide a spoken message in mono underneath a stereo track of synth parts consisting of a bass, pad, and lead synth. This piece will take a similar approach to that of the example Gordon<sup>17</sup> showed by making use long reverb tails and whispering to obscure the spoken words, he also puts his message in reverse to further obscure the content.

Rather than reversing the message in this piece, the audio is instead stretched out to 3 times its original length using the plugin “PaulXstretch”<sup>18</sup>. This makes the message harder to distinguish as words when listening in stereo with the synth parts but it is still distinguishable when listened to in isolation through mono.

In addition to this the example shown by Gordon features a lot of noise. Implementing noise into this composition assists in covering the spectral content required to fully mask the message to the

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<sup>17</sup> Gordon, Mick, “DOOM: Behind the Music”, Youtube, uploaded by GDC Festival of Gaming Aug 22, 2017.

<sup>18</sup> PaulXstretch plugin <https://sonosaurus.com/paulxstretch/>

point of inaudibility. The noise track has a slow LFO applied to the low pass filter cutoff to mimic any sibilance caused by the spoken word and obscure it even further. Using all of these techniques the piece features a short synth tune when listened to in stereo but changes to the message “you are listening in mono” when summed to a mono output.

These pieces of music utilised the mixing techniques related to masking previously researched in the literature review, however it applied the opposite approach to achieve the most masking possible. For example the technique “mirrored equalisation” as mentioned by Wakefield and Dewey<sup>19</sup> would normally boost the prominent frequencies of a select element you wish to cut through the mix while attenuating the same frequencies in other sounds. In the case of this project the opposite was applied, attenuating the prominent frequencies of the folk/ piano tracks while boosting the same frequency in their stereo counterparts (rock/ orchestral). Wakefield and dewey also discuss how stereo panning can reduce masking, in the case of this project all elements of the mono track are central and the stereo duplicates are hard panned left and right with the slight difference of one being phase inverted. This essentially means that there is no stereo panning in the mix and should add to the amount of masking achieved.

Use of compression was also vital in the masking process. Transient information such as the initial pluck of a guitar string or the hammer strike of a piano were most likely to cut through the mix and be audible when listening in stereo. Applying a compressor with a fast attack time, hard knee and high ratio would tame these transients to have a more consistent and easily masked sound.

Effects such as Reverbs and Delays were used sparingly in the Rock/Folk piece as these effects can quickly add up in frequency content and create unwanted muddiness of the mix. This is especially true when the audio contains two different pieces of music. For this reason any reverbs or delays used had a significant high pass filter applied to them to avoid low frequency build up issues.

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<sup>19</sup> Wakefield, Jonathan; Dewey, Christopher “*An investigation into the efficacy of methods commonly employed by mix engineers to reduce frequency masking in the mixing of multitrack musical recordings*”

The same approach was taken as Gordon<sup>20</sup> for creating the phase cancellation effect that is central to this project's methodology.

Once all the elements of the pieces were mixed individually the stereo version (rock/orchestral) was duplicated, each duplicate was then hard panned left and right and the phase of one of them was inverted. It is important to note that these duplicates were both mono bounces of their multi track mixes. This is to ensure that the duplicates have no volume differences from stereo tracks within the mix that may result in non zero cancellation when summed. Both this duplicate stereo version and the mono alternative were then mastered to -14LUFSi and the mono version was lowered to a volume below that established in the masking perception test for the final bounce of the audio files combining the 2 different versions into 1 file.

This results in the (rock/ orchestral) music being heard in when played through a stereo device but when played through mono device the phase cancellation occurs and the mono ( folk/ piano versions) hiding underneath are revealed.

It is important to note that these final versions are intended to be played as WAV files rather than a compressed format such as MP3. This is because in a compressed audio format the masked content is automatically reduced in quality by the algorithm which may result in strange artefacts being heard in the mono versions. However as a WAV file this isn't an issue and both the mono and stereo versions retain high quality audio.

### **Masking perception test.**

A simple test was carried out to discover the volume difference needed for one object to be complete masked by another to the point of being inaudible. In this test several participants were gathered and played a short loop of a section of the rock/folk music. In this case, the rock and folk were on separate tracks in a pro tools session. Both of these audio files had previously been mastered to -14LUFSi and -1.1 true peak with consistent dynamics to ensure the test is as fair as possible. All tests were also done using the same headphones and playback device in a silent room.

Participants were played the loop of the rock music until they were familiar with the content. The folk music was then gradually turned up on the fader by the examiner while the rock music was playing and the participants were asked to say "stop" as soon as they noticed the folk music was audible.

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<sup>20</sup> Gordon, Mick, "DOOM: Behind the Music", Youtube, uploaded by GDC Festival of Gaming Aug 22, 2017.

This test was done at 2 different volume levels. The first being a “normal” listening level (50% volume on device) and the second being a “quiet” listening level (20% volume). This was done to discover if there would be an alternative answer in the difference of volume needed to hear the masked audio at different volume levels relating the equal loudness contours researched from Acoustics and Psychoacoustics<sup>21</sup> in the literature review. Position of the fader on the folk track was noted to establish a minimum volume difference required to achieve total masking.

### **Listener device survey**

A survey was created with the aim of gathering quantitative data on what devices people use to listen to audio.

In this survey several questions were asked including;

- A ranking of what devices they use the most to listen to music.
- How often they would hear music through a phone speaker or smart speaker.
- If they own a smart speaker or have one in their household.
- How many speakers they believe are on their mobile phone.

They were then asked to listen to a short clip of the music created using the phase cancellation technique and asked if they heard a folk song or a rock song when listening.

In theory those who listened on a stereo device should have heard a rock song while those who listened on a mono device would have heard a folk song.

This survey should offer an insight into what devices the average listener uses to consume audio and should reinforce the data gathered from IAB Ireland.<sup>22</sup>

### **Mixing Engineer Questionnaire**

A professional mixing engineer was then asked several questions on mono compatibility in music and how they approach it in the mixing process. In this case the mixing engineer asked was Kieran Lynch. The questions asked include

- During the mixing process do you frequently check the mix through mono output? why / why not?

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<sup>21</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

<sup>22</sup> IAB Ireland “listen up Ireland 2024”.

- Do you feel it is worth using stereo widening effects for a better stereo image at the cost of more phase cancellation in mono?
- Do you feel that mono listening is still relevant in 2026?

This questionnaire offers an insight into a professional approach to mono compatibility and a professionals opinion on the importance of mono listening.

## Analysis

### Implementation and effectiveness of the technique

The mono and stereo versions of the pieces were analysed using the “*MeldaMultiAnalyser*”<sup>23</sup> Plugin. This allowed the frequency content of the two audio files to be compared in real time and confirm that the content of the mono version was sufficiently covered by the stereo versions with a large volume difference between them proving that masking is taking place. These comparisons were done using the separate stereo and audio files with the volume difference used in the final master included.

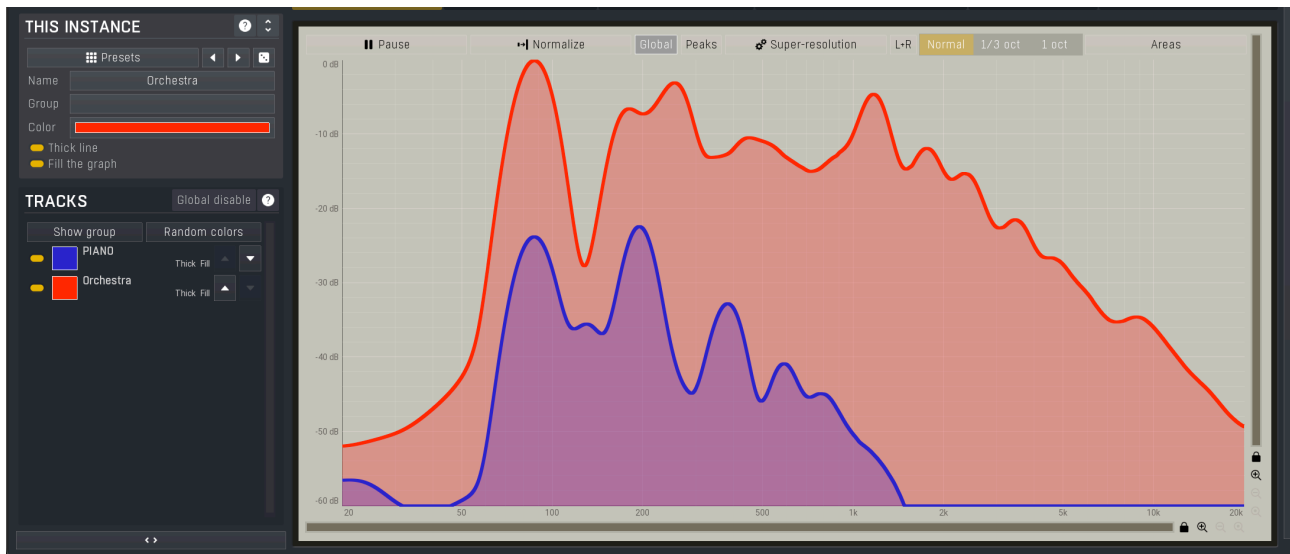
For example the following images show a moment of comparison between the mono and stereo audio files.

#### **1 Rock(red) vs Folk ( green)**

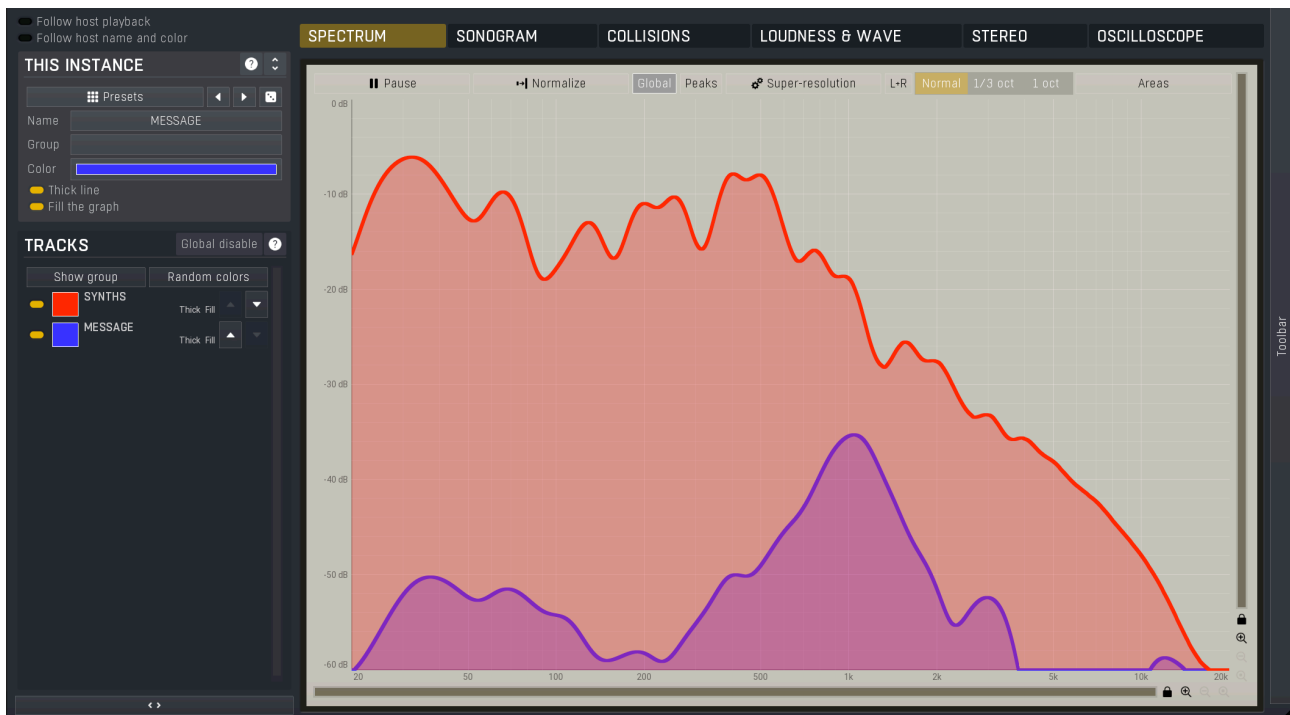


#### **2 Orchestra ( red) vs Piano reduction ( Blue)**

<sup>23</sup> MeldaMultiAnalyser <https://www.meldaproduction.com/mmultianalyzer?srsId=AfmBOool6jG5x3LIl9a6comnJRAc5s81R3QFBpGWZS9fNqaXeT3dM4hu>



### 3 Synths ( red ) vs hidden message (blue)



Through observation of these graphs as the audio file is playing, a large amount of masking is confirmed with the masker clearly having a large volume gap between it and the maskee whilst also covering more of the frequency spectrum.

### Masking perception test results

Participants were asked to say stop when the folk tune was audible in comparison to the rock music and the level of the folk music was noted. This was done at both at both 50% volume and 20% volume. 6 people took part in the test. The results of the test can be seen in the following image

Normal volume	quiet volume
-27.7	-19.5
-25.6	-20.6
-21.8	-18.2
-24.3	-17.2
-29.7	-19.8
-22.2	-16.1
avg = -25.2	avg = - 18.5

The figures shown above are the positions of the fader on the folk track that the participant first noticed the folk audio through the rock music. The Rock music was left 0 on the fader position. Both tracks were previously mastered to -14LUFSi and -1.1 true peak.

These results clearly show that participants found it harder to perceive a masked element when listening at a lower volume as the fader on the folk track is much higher in level. This confirms the relationship between equal loudness contours and masking speculated from research of Acoustics and psychoacoustics<sup>24</sup> in the literature review.

The levels gathered also provided an informed statistic on the minimum difference in volume that the stereo and mono versions of the tracks should have to achieve complete masking.

This result was used in the combination process of the two versions placing the mono version at least below -25.2 on the fader after both were mastered to -14 LUFSi -1.1True peak.

This test could have been improved with a larger amount of participants and could have possibly given a different average end result.

### **Listener device survey results**

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<sup>24</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

22 participants took part in the listener device survey.

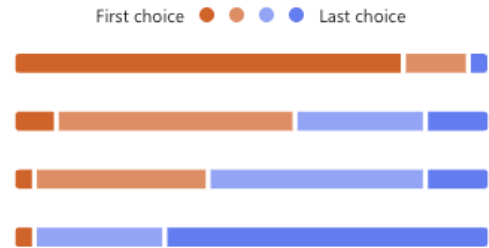
The results for the questions are as follows

**1: Please rank what devices you use the most to listen to music ( 1 being the most used at the top of the list)**

22 Responses

Rank Options

- 1 headphones
- 2 bluetooth speaker
- 3 phone speakers
- 4 smart speaker, eg Amazon alexa / Google home



**headphones**

1st choice: **81.8%**  
 2nd choice: **13.6%**  
 4th choice: **4.5%**

**bluetooth speaker**

1st choice: **9.1%**  
 2nd choice: **50%**  
 3rd choice: **27.3%**  
 4th choice: **13.6%**

**phone speakers**

1st choice: **4.5%**  
 2nd choice: **36.4%**  
 3rd choice: **45.5%**  
 4th choice: **13.6%**

**smart speaker, eg Amazon alexa / Google home**

1st choice: **4.5%**  
 3rd choice: **27.3%**  
 4th choice: **68.2%**

As the data shows, headphones were by far the most popular device with 81.8% of people ranking it as their most used. This means that majority of the time they would be listening in stereo, however a number of people did rank phone speakers or smart speakers as a commonly used device meaning there is a strong possibility they are listening in mono when using these devices.

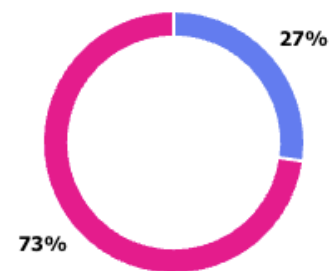
**2: How often would you hear music through a mobile phone speaker or a smart speaker (Amazon alexa/ Google home etc..)**

- never **9.1%**
- rarely **22.7%**
- sometimes **36.4%**
- often **13.6%**
- Very often **18.2%**

This question shows that majority of people will hear music through a device that could be mono frequently with only 31.8% of people saying that they would rarely or never hear music through these devices.

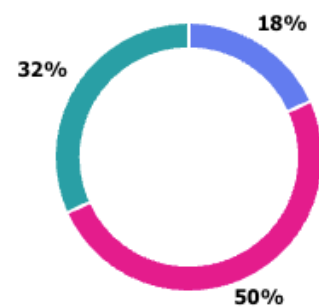
**3: Do you own a smart speaker (amazon alexa, google home etc..) or have a smart speaker in your household?**

● Yes	6
● No	16



**4: How many speakers are on your mobile phone?**

● 1	4
● 2	11
● not sure	7



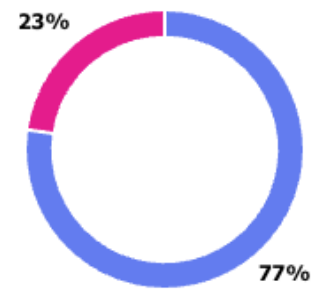
This question aimed to see if people were aware if their phone was mono or stereo and gauge an estimate as to how many mono phones are used.

**5:**

**Please listen to the audio attached.**

**When listening to the audio did you hear a rock song or a gentle folk song?**

● Rock	17
● Folk	5



The results of this question not only confirms that the masking and phase techniques were established correctly but it also confirms that some participants were using a mono device to listen to the audio included in the survey. The participants were not told which device they should use to listen to the audio giving a genuine result of what they would listen to audio with normally.

### **Engineer questionnaire results**

Professional Mixing engineer Kieran Lynch was asked several questions relating to mono compatibility. The questions he was asked and his answers are as follows;

**Q 1 During the mixing process do you frequently check the mix through mono output? why / why not?**

A:

-“Yes, to check for phase cancellation in the low frequencies and any midrange masking” - Kieran Lynch

This answer confirms that checking the mono sum of stereo mixes is standard practice and it also reinforces the point made by Wakefield and Dewey<sup>25</sup> that more masking occurs in mono than when elements are panned in the stereo field.

**Q 2 Do you feel it is worth using stereo widening effects for a better stereo image at the cost of more phase cancellation in mono?**

A:

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<sup>25</sup> Wakefield, Jonathan; Dewey, Christopher “An investigation into the efficacy of methods commonly employed by mix engineers to reduce frequency masking in the mixing of multitrack musical recordings”

-“Yes, but this has to be monitored. In general, stereo widening is most effective from 1KHz up and introduces less phase cancellation. It is when stereo widening is applied to low frequencies that the issues arise.” - Kieran Lynch

**Q 3 Do you feel that mono listening is still relevant in 2026?**

A:

-“ Yes, as many public address systems in restaurants, clubs and shopping centres still operate in mono for a more coherent distribution of sound within a large omnidirectional space.” - Kieran Lynch

This answer confirms that mono playback is still considered as an important medium from a professionals perspective and added the cases of PA systems and venues to the reasons for mono use in addition to the devices previously mentioned in this thesis.

## Discussion

### Reflection on the musical pieces.

The final versions of the pieces of music created turned out well and implemented the phase cancellation technique used by Gordon<sup>26</sup> successfully resulting in the desired effect for each piece such as the genre swap of the rock/folk piece and the piano reduction of the orchestral piece.

The pieces also sufficiently mask the mono versions under the stereo versions by applying the opposite practice to techniques such as those outlined by Wakefield and Dewey<sup>27</sup> or Wichern, Robertson and Wishnick <sup>28</sup>. When listening in stereo it is very difficult if not impossible to hear the mono track being obscured underneath.

The orchestral piece could be improved upon with more dynamic changes between sections. Originally the intent was to gradually build the piece up in dynamics however doing this creates an

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<sup>26</sup> Gordon, Mick, “DOOM: Behind the Music”, Youtube, uploaded by GDC Festival of Gaming Aug 22, 2017.

<sup>27</sup> Wakefield, Jonathan; Dewey, Christopher “*An investigation into the efficacy of methods commonly employed by mix engineers to reduce frequency masking in the mixing of multitrack musical recordings*”

<sup>28</sup> Wichern, Gordon; Robertson, Hannah; Wishnick, Aaron, “*Quantitative Analysis of Masking in Multitrack Mixes Using Loudness Loss*”

inconsistent masking relationship between the orchestra and the piano, this could cause the piano to be audible during lower dynamic sections. For this reason the piece instead starts off with high dynamic and remains that way throughout.

Making use of this technique does have major downsides regarding the overall quality of the audio. Stereo panning is not possible, if any element is panned to one side it will result in non zero cancellation when summed to mono, this removes any sense of stereo depth from the mix.

A major volume difference is required for the technique to successfully hide the mono version.

If this technique was used on a compressed audio format such as Mp3, there will be undesirable artefacts when listening in mono. For this reason the project artefacts are intended to be listened to as a WAV file.

The dynamic content of the music created is also highly limited for the technique to consistently work. If at any point there was a significant drop in dynamics of the stereo music, the ratio of volume between the stereo and mono audio or the frequency content needed to mask it may no longer be present and the mono audio may become perceivable.

The technique does however allow for a creative way to hide content within an audio file whether it be for artistic purposes such as the genre switch from rock to folk or practical purposes such as the built in piano reduction from the orchestral arrangement.

The amount of mixing techniques required to achieve the sufficient masking varied greatly between the different pieces, the workload of mixing the Rock/Folk piece was significantly higher than the orchestral piece. This is because the piano piece has a far simpler sound with less transients than tracks such as an acoustic guitar or banjo. In the case of the Orchestral/Piano piece only a small amount of equalisation and compression was necessary, while this was used extensively across the Rock/Folk tracks.

### **Masking perception test.**

The results of the masking perception test were highly informative and useful for establishing the minimum volume difference required to achieve total masking. The test also confirmed the difference in masking perception at different audio levels in relation to the quality loudness

contours<sup>29</sup>. This test could have been improved upon had more people taken part to achieve a more accurate result but the results gathered were useful regardless of the amount of people.

### **Listener devices survey**

The information gathered in this survey was highly relevant to the project and confirmed the use of mono devices by consumers, justifying the applicability of the technique this project aimed to make use of. The results of this survey also fill in any gaps in information that may have been found in the survey done by IAB Ireland<sup>30</sup> from the literature review such as clarifying if people are using the speakers on their mobile phones to listen to audio.

The survey also confirmed that several participants used a mono device to listen to the audio provided by saying that they heard a folk track, proving that in the case of mono listeners such as these mono incompatibility could drastically change what they hear on their devices from a stereo device.

### **Engineer questionnaire**

The engineer questionnaire offered a valuable insight into how a professional mixing engineer views mono compatibility and where issues arise with phase cancellation when mixing. It also confirmed the relevance of mono listening in 2026 by highlighting several systems that make use of mono sound.

### **Project management.**

The structure of this project was clearly divided into separate tasks such as the composition and recording process, masking perception tests, mixing and mastering with implantation of the phase inversion technique, the listener survey and engineer survey. All of these tasks culminated in results that reinforce research undertaken in the literature review.

The scope of the project was initially set to include 2-4 different compositions and this goal was met with the resulting 3 produced. However the time and attention given to the pieces varied as some such as the rock/folk piece had a far lengthier mixing process as well as spread out studio dates for recording tracks.

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<sup>29</sup> M. Howard David, A.S Angus Jamie, *ACOUSTICS AND PSYCHOACOUSTICS FOURTH EDITION*, Focal press, 2009

<sup>30</sup> IAB Ireland “listen up Ireland 2024”.

## **Conclusion**

This project and thesis successfully made use of mono incompatibility as a creative tool to create several unique compositions. The application of total phase cancellation when played through a mono device in addition the use of masking to obscure mono content achieved the desired goals set out by the different pieces of music such as the genre swap of Rock to folk, the piano reduction from a full orchestral arrangement or revealing hidden messages. This was achieved through the interpretation of mixing techniques researched in the literature review combined with data gathered from the masking perception test to inform volume ratios of the stereo and mono audio.

The project also offered an insight into the use of listening devices through a survey particularly focusing on the use of mono devices by the average consumer and this was further reinforced by the varied results in answers when asked what was heard in the attached audio file that makes use of the phase inversion technique. The opinion of a professional mixing engineer further reinforced research into mono incompatibility problems from the literature review such as that of F.K Harvey, Edward Euke<sup>31</sup> as well as highlighting other possible use cases of mono listening and why it is still as relevant form of audio in 2026.

Future directions for the project could include investigating minimising the required volume difference between the stereo and mono parts whilst retaining complete masking and further consumer surveys to get a more accurate representation of mono devices used and their relevance. The production of the pieces could also be improved to have the same dynamics reflected in the stereo and mono versions, this would allow for more interesting compositions whilst retaining the same volume relationship between the files.

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<sup>31</sup> F.K Harvey, Euke Edward, “*Compatibility problems in two-channel stereophonic recordings*” Audio engineering society 13th annual meeting, 1961

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