Auditory Perception & Hearing Science
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AB Comparative Identification of Musical Samples via WAV, FLAC, and AAC Codec

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ABSTRACT

The aim of this study was to determine if listeners could correctly identify WAV, FLAC, and AAC codec files within three different genres. A total of 11 subjects participated in a two-part AB test and were instructed to identify the WAV codec file in both parts. Part one consisted of WAV codec files of CD quality and AAC codec files in 32, 64, 80, 96, 160 kbps. The data was analyzed using a non-parametric ANOVA on the binomial. The results suggested that subjects could not identify the WAV codec file for the country or rock songs at 96 or 160 kbps. While subjects were able to identify the pop song at 96 kbps, they could not at 160 kbps. Part two consisted of WAV and FLAC codec files both at 44.1 kHz and 16-bit. The data was analyzed using a binomial test on the correct number of "hits" per subject. The results suggested that subjects could not identify the WAV codec files across genres when compared to FLAC codec files.

1 Introduction

In recent years, with the arrival of online music streaming, many artists and industry professionals have expressed interest in releasing audio and music content in a variety of different digital file formats, including WAV, FLAC, and AAC codec. However, this curiosity raises questions. Can listeners tell the difference between WAV and FLAC codec files? Can listeners tell the difference between WAV and AAC files? Before attempting to answer these questions, each of these audio file formats should be discussed.

The Waveform Audio file, or WAV, is the standard audio format within the music recording industry. it contains uncompressed raw data that is large in nature. It was originally developed by IBM and Microsoft and released in 1991 [12].

The Free Lossless Audio Codec file, or FLAC, is a lossless compression file format that first emerged in 2001. While FLAC codec files are up to six times larger than an MP3 codec file, they can be half the size of a WAV codec file [13].

The Advanced Audio Coding, or AAC, codec file was created in 1994 and finalized in 1997 by the MPEG-2 Audio committee. The goal of creating this codec was to make the audio quality "indistinguishable" for data rates above 384 kbps [10]. While AAC is a lossy format much like MP3, AAC codec differs in that it retains more bits, meaning that it does not delete as much information as the MP3 codec does [11]. The AAC codec format is mainly used by Apple Music as their default encoding method for streaming music.

This study will attempt to answer the questions surrounding if listeners can identify between WAV, FLAC, and AAC codec files.

2 Prior Art

Previous research has mostly been done comparing WAV and MP3 codec files. In one study, researchers examined listener preferences between CD quality WAV codec files and MP3 codec files of varying bitrates [2]. After conducting an A/B comparison test, the findings suggested that listeners preferred CD quality when compared to MP3 files below 192 kbps without genre being a factor [2].

Another study focused on if listeners could discriminate between MP3 compressed instrument tones from the original sounds [8]. They found that listeners could discriminate between the two sounds when the MP3 bit rate was low, mainly below 64 kbps, and could not when the bitrate was high, above 128 kbps [8]. Additionally, they found that the discrimination between instrument tones were affected by bit rate. Listeners had a harder time discriminating with all bitrates with French horn and an easier time with clarinet [8].

A third study focused on determining if loop length and genre played a factor in listening tests when discriminating between MP3 and WAV files [4]. The results suggested that listeners had a better success rate of discriminating between the two codec files when the loop length was longer than 2 seconds. They also discovered that the effect of genre was not statically significant [4].

3 Methods

Based on the understanding of these codec file formats and the results of prior studies, it is believed that subjects will perform at chance levels when asked to compare WAV and FLAC codec files for all genres as well as perform at chance levels when asked to compare WAV and AAC codec files above 96 kbps for all genres. The null hypothesis is that subjects will not be able to identify between WAV, AAC, or FLAC codec files of all bit depths and genres.

The independent variables for this test include genre and the individual audio files. The dependent variable was the measure of subjects' responses. They were grouped by genre and bit depth, and the correct number of "hits" were used for the analysis.

Three songs were chosen from various genres to be the stimuli, shown in Table 1.

Table 1. Songs and genres that were chosen for stimuli.

Genre	Song	Artist
Country	"It Happens"	Sugarland
Pop	"Just Dance"	Lady Gaga
Rock	"Paradise City"	Guns n' Roses

Each song was copied from their respective CDs to create the WAV codec files with sample rate of 44.1 kHz and bitrates of 16-bits. Each WAV codec file was then transcoded using Pro Tools and Logic Pro software to create each FLAC codec file with 44.1 kHz, 16-bit quality as well as each AAC codec files at varying bit depths of 32, 64, 80, 96, and 160. Each stimuli file was shortened to only 5 seconds long.

The test was conducted as an AB test and consisted of two parts. In total, subjects completed 108 trials with 90 in part one and 18 in part two. The 11 subjects who participated were audio engineering graduate students between the ages of 21-25 with varying backgrounds in audio and music. Open-back headphones of good quality were used to administer the test. Subjects also had two-minute breaks after every 20 trials and at the end of both parts.

Part one included WAV and AAC codec files. The three WAV codec files were paired with each bit depth and grouped by genre. In total, each pair were played six times. All trials were randomized and were played back via Apple Music on a 2015 MacBook Pro. Subjects were instructed to identify which of the two audio clips was the WAV file.

Part two consisted of WAV and FLAC codec files. As there were only one WAV and one FLAC codec file per genre, each pair was played six times for a total of 18 trials. All trials were randomized and were played back via Apple Music and Vox: MP3 and FLAC Audio Player on a 2015 MacBook Pro. Subjects were asked to identify once again the WAV file.

4 Results

The data from part one was ran through a normality test where it was shown that the data was not normally distributed. A non-parametric analysis of variance on the binomial was conducted on the data first by the correct number of "hits" and grouped by bit depth. The results indicated that the effect of bit depth was statically significant when $\alpha = 0.05$, $X^2 (4, N = 18) = 46.678$, $p < .01$, as shown in Figure 1.

Compare Multiple Related Samples			
ANOVA			
N	18	*Degrees of Fr*	4
Corrected for ties			
Chi-square	53.17722	*p-value*	0.0000000001
Not corrected for ties			
Chi-square	46.67778	*p-value*	0.0000000018
Statistics			
VAR	Average rank	Sum of Ranks	Mean
32	4.38889	79	10.55556
64	4.13889	74.5	10.33333
80	2.88889	52	9.00000
96	2.19444	39.5	8.00000
160	1.38889	25	6.27778

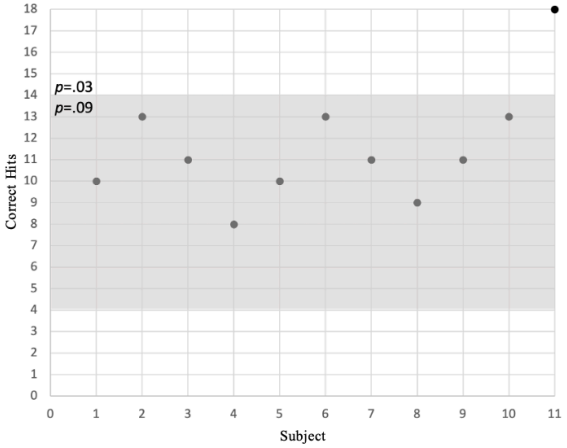
Figure 1. Non-parametric ANOVA on the binomial response by "hit" and grouped by bit depth results.

Another analysis of variance on the binomial was conducted, this time by the correct number of "hits" and grouped by genre. The results indicated that the effect of genre was not statistically significant. $X^2(2, N = 30) = 1.52$, $p > .05$, as shown in Figure 2.

Compare Multiple Related Samples			
ANOVA			
N	30	*Degrees of Free*	2
Corrected for ties			
Chi-square	2.49	*p-value*	0.29
Not corrected for ties			
Chi-square	1.52	*p-value*	0.47
Statistics			
VAR	Average rank	Sum of Ranks	Mean
Country	2.02	60.5	8.77
Pop	2.15	64.5	9.17
Rock	1.83	55	8.57

Figure 2. Non-parametric ANOVA on the binomial response by "hit" and grouped by genre results.

The correct number of "hits" by subject in the part two data were calculated and a binomial test was conducted. The results indicated that the data is not statistically significant, $p > .05$, as shown in Graph 1.



Graph 1. Part two binomial test results of correct "hit" by subject.

5 Discussion

This test attempted to answer the questions on if listeners could identify WAV codec files when compared to FLAC codec files, if listeners could identify WAV codec files when compared to AAC codec files and at what bit depths, and if genre played a role. These findings suggest that subjects could not identify the WAV codec file for the country or rock songs at 96 or 160 kbps. While subjects were able to identify the pop song at 96 kbps, they could not at 160 kbps. Overall, the results suggest that subjects are unable to identify the 96 and 160 kbps recordings on average across genres. Additionally, these results also suggest that subjects could not identify the WAV codec files across genres when compared to FLAC codec files.

These results support earlier studies in that genre did not play a role and that subjects could not identify WAV codec files when the AAC file was 96 kbps or 160 kbps [2] [8]. Additionally, these results both reject and support the null hypothesis as subjects are able to identify between WAV and AAC codec files above 96 kbps, but they could not correctly identify between WAV and FLAC codec files.

Furthermore, these results confirm the understanding of the differences between uncompressed, lossy, and lossless file types.

6 Conclusions

Regarding the music industry, these findings can help companies and artists big and small. For artists, especially up-and-coming independent artists who do not have a contract with a label, these results suggest that they do not have to have large WAV codec files of their music in order to distribute it. Many do not have the financial capabilities of affording the necessary digital storage for these large WAV files, so knowing that they can instead distribute their music using high-quality AAC or FLAC codec files can help them on their musical journey while not consuming too much storage space. This also means that the average listener from these artists will not be able to tell the difference between the quality of music from these artists compared to those signed to large recording labels.

For companies, especially streaming services such as Spotify, Apple Music, and Amazon Music, these findings indicate that they do not have to require only WAV codec files to be submitted for listeners to hear high quality music. By recommending high quality FLAC and AAC codec files instead, they would have the ability to hole more music from more artists without having to increase the amount of cloud storage they possess. Spotify has already realized this, and they now highly recommend FLAC codec files be submitted instead of WAV codec files [9].

7 Future Research

The focus of this experiment was to determine if listeners could identify between WAV, FLAC, and AAC codec files. This test was administered with some limitations. The two-part test had to be completed within a 75-minute time frame in one day. Additionally, two very different music playing applications had to be used, which furthered the risk of human error in playback. It also brought technical difficulties, as the applications had difficulty cooperating with playback.

If this test was administered again, more time would need to be allocated so that subjects are able to receive proper breaks during testing as well as allowing for more trails to be ran for each part. There would also need to be a better way of conducting the playback of each trial instead of using two very different applications. Further, a longer test would allow more genres to be included as well as a wider range of bit depths. Additionally, this test could be conducted by using recordings of sonatas played on individual instruments instead of recorded popular music and genres.

References

[1] A. Harris, "Do Young People Actually Care About the Quality of Their MP3s," in *AES 130th Convention*, London, UK, 2011.

[2] A. Pras, et. al., "Subjective Evaluation of MP3 Compression for Different Musical Genres," in *AES 127th Convention*, New York, USA, 2009.

[3] D. Martin, et al., "Can We Hear the Difference? Testing the Audibility of Artifacts in High Bit Rate MP3 Audio," in *AES 141st Convention*, Los Angeles, USA, 2016.

[4] D. Martin and R. King, "The Effect Loop Length and Musical Material on Successful Discrimination Between MP3 and WAV Files," in *AES 140th Convention*, Paris, France, 2016.

[5] ISO/IEC JTC1/SC29/WG11 MPEG, IS13818–7, "Information Technology – Generic Coding of Moving Pictures and Associated Audio Information – Part 7: Advanced Audio Coding", 2006.

[6] J. Lacroix, et al., "Lossless Audio Checker: A Software for the Detection of Upscaling, Upsampling and Transcoding in Lossless Musical Tracks," in *AES 139th Convention*, New York, USA, 2015.

[7] K. Brandenburg, "MP3 and AAC Explained," in *AES 17th International Conference: High-Quality Audio Coding*, Florence, Italy, 1999.

[8] L. Chung and A. Horner, "Discrimination of MP3-Compressed Musical Instrument Tones," *Journal of the Audio Engineering Society*, vol. 56, no. 6, pp. 487-497, 2010.

[9] "Managing Your Music," *Spotify for Artists*. [Online]. Available: https://artists.spotify.com/help/managing-your-music. [Accessed: 11-Apr-2022].

[10] M. Bosi and R. E. Goldberg, "Chapter 13 MPEG-2 AAC", in *Introduction to Digital Audio Coding and Standards*, Kluwer Academic Publishers, 2003, pp. 333-370.

[11] Sage Audio, "AAC or MP3 – What's the Best Lossy File Type?," N.D.. [Online]. Available: https://www.sageaudio.com/blog/mastering/aac

-or-mp3-whats-the-best-lossy-file-type.php. [Accessed: 27 Apr. 2022].
[12] T. Fisher, "What are WAV and WAVE Files," Lifewire, 11 September 2020. [Online]. Available: https://www.lifewire.com/wav-wave-files-2622395. [Accessed: 27 April 2022].
[13] T. Pendlebury, "What is FLAC? The High-Def MP3 Explained," CNET, 28 October 2018. [Online]. Available: https://www.cnet.com/tech/home-entertainment/what-is-flac-the-high-def-mp3-explained/. [Accessed 27 April 2022].