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An Investigation into the Relationship Between the Subjective Descriptor Aggressive and the Universal Audio 1176 FET Compressor

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ABSTRACT

In popular music productions, the lead vocal is often the main focus of the mix and engineers will work hard to impart creative colouration on this source. This paper conducts listening experiments to test if there is a correlation between perceived distortion and the descriptor "aggressive" which is often used to describe the sonic signature of the Universal Audio 1176. The results from this study show compression settings that impart audible distortion are perceived as aggressive by the listener and there is a strong correlation between the subjective scores for distortion and aggressive. It was also shown there is a strong correlation between compression settings rated to have high aggressive scores and the audio feature roughness.

1 Introduction

In addition to general dynamic range control, it is common for music producers to use dynamic range compression (DRC) for colouration and non-linear signal processing techniques, specifically to impart distortion onto program material. Furthermore, the Universal Audio 1176 compressor (originally named Urei 1176) is a popular choice for this style of colouration, particularly when processing vocals in rock productions [1,2]. Users describe the sound quality of vocals processed in this manner by using a number of subjective descriptors. This paper investigates one of the most common descriptors "aggressive" to determine what it means at an objective level and answer empirically how an aggressive sound quality can be achieved when using the 1176 and more broadly DRC in vocal productions.

To answer these questions three studies were carried out. Firstly, a qualitative study was conducted that asked a number of experienced engineers to rate the appropriateness of commonly used descriptors in a similarity matrix. The results suggested the descriptor aggressive was actually a synonym for distortion. Thus, a second stage of testing conducted a subjective listening test using the Audio Perceptual Evaluation (APE) method from the Web Audio Evaluation Tool (WAET) [3]. This tested whether listeners rated mixes with vocals compressed by a hardware UA

1176 and using settings measured to have large amounts of Total Harmonic Distortion (THD) as the most aggressive. Finally, a second listening test was carried out to ascertain whether distortion, timing behaviour or a mixture of both were the most important factors in creating compressed audio perceived to be aggressive. The reason for this test was due to the 1176 being known as a fast acting compressor (particularly when working with time constant settings that will be addressed later) therefore it could be argued its fast timing is creating the aggressive sonic signature rather than distortion. This was tested in a second listening experiment that had vocals processed with a clean software compressor (measured with 0% THD) and set to mimic the timing behaviour of the 1176 as well as material compressed with a hardware 1176 and measured to have 1.58% THD. The Klanghelm DC8C software compressor [4] was used for this test as it allows user control over a range of design traits that can be used to match the behaviour of a number of compressors. Most importantly, it does not generate any distortion, even at the fastest time constants, when used in its clean mode.

2 Qualitative Study

An online questionnaire was created that among other questions asked experts to describe the sound quality of vocals compressed with an 1176. Judgement sampling (as opposed to random sampling) was used to select experienced engineers and academics to complete the questionnaire. For an expert to be included they had to be knowledgeable in music production and familiar with the 1176. Judgement sampling does however have its limitations and is prone to bias [5].

The questionnaire was completed by 35 respondents. Table 1 shows the more common words used to describe the sound quality. To reduce the amount of words in the table only those recorded more than once have been included. As can be seen the descriptor aggressive is the most popular followed by the word gritty which is arguably a synonym for distorted.

Descriptor	Frequency of occurrence
Aggressive	6
Gritty	5
Forward	4
Midrange	4
Presence	4
Full	3
Sparkly	2
Up Front	2
Pumping	2
Smooth	2

Table 1. Descriptors used for 1176 vocal compression

To help clarify the real meaning of the descriptors by looking for associations between them a second stage of testing asked respondents to rate the appropriateness of the most popular descriptors in describing the sound quality of a given compression technique. Respondents completed this task online and recorded their scores on a similarity matrix. This was conducted by creating an online spreadsheet that had compression activities on the X-axis and descriptors on the Y-axis. Respondents then allocated each descriptor a score between 0-4 to rate its appropriateness (zero being totally inappropriate and four being totally appropriate). As a descriptor could relate to more than one compression technique the respondents were instructed they could rate the descriptor for as many techniques as they felt appropriate. The compression techniques included were: linear processing, colouration general, colouration frequency related, distortion, modulation/altering rhythmic feel, general dynamic range control, attenuating transient, accentuating transient. The authors selected these techniques based on prior research which indicated these techniques were commonly used by industry professionals in the production process.

The similarity matrix was completed by twelve respondents, all of which had participated in the first stage. Analysis was conducted on the mean scores of the compression techniques in relation to the word aggressive. The results show that there was a statistically significant difference between groups (compression techniques) as determined by one-way ANOVA (F (7,88) = 3.854, p =.001). A Tukey post hoc test revealed that the experts considered the descriptor aggressive was statistically significantly lower for the compression techniques “general dynamic range control” (p = .027), “modulation” (p=.002) and “linear processing” (p=.001) compared to the compression technique “distortion”. There was no statistically significant difference between the descriptor aggressive score for the compression techniques “colouration general” (p = .229), “colouration frequency related” (p = .171), “attenuating transient” (p = .088) and "accentuating transient" (p = .124) compared to the compression technique “distortion”. The reason for the lack of significance between these techniques is thought to be as a result of the potential for distortion to reshape the transient portion of audio material (particularly true for attenuating the transient) in addition to the introduction of harmonic components that lead to colouration. Therefore, it appears from this study engineers consider the descriptor aggressive to relate to compression techniques that distort and colour the audio and reshape the transient portion of program material.

3 Selection of Settings

Content analysis was conducted on 1176 vocal compression settings by analysing presets created by professional engineers for the 1176 UAD plugin [6]. This revealed that specific combinations of attack and release settings were regularly used, with release positions between 5-7 and attack positions between 1-3 being most common. Additionally, it was noted that the 4:1 ratio was often implemented for general vocal settings and the all buttons mode (a popular “special mode” achieved by depressing all ratio buttons simultaneously) was employed for highly coloured processing. Table 2 shows how frequently particular settings are used in the vocal presets. As can be seen in the bottom two rows of the table positions between 1 to 3 are most common for attack and positions between 5-7 most common for release.

Based on these findings, the following attack and release combinations were used in the following listening experiment (attack is abbreviated to A and release is abbreviated to R): A3R7, A1R7, A3R5, A1R5. The combinations were used in both the 4:1 and all buttons ratio modes. More general research of content pertaining to the 1176 [7,8] showed the A3R7 combination was a popular setting for a range of instrument sources. Therefore, the settings used in the experiment are considered by the authors to be representative of real working scenarios. It is also worth bearing in mind the attack control on the 1176 is quoted as ranging between 20-800 microseconds and critical listening by the authors revealed very little difference in sound quality between attack times from positions 1 to 3. Additionally, the reader should consider the attack and release controls on the 1176 work counter clockwise, meaning attack and release positions 7 are the fastest and 1 the slowest.

Setting value	Percentage of time release setting used in presets	Percentage of time attack setting used in presets
1	0%	46.67%
2	0%	20.00%
3	0%	20.00%
4	0%	6.67%
5	18.18%	6.67%
6	18.18%	0.00%
7	63.64%	0.00%
1 to 3	0%	86.67%
5 to 7	100%	6.67%

Table 2. Popularity of 1176 time constant settings

4 Distortion Measurements

A series of THD measurements were made on the 1176 at various attack and release settings and showed distortion artefacts reduced significantly when using release times slower than position 5 and that the attack control had a smaller effect on the reduction of distortion. Furthermore, higher ratios had the effect of increasing non-linearity with the all-buttons mode increasing non-linearity significantly more than any other ratio. Figure 1 illustrates the effect of lengthening the attack and release time on THD. The measurements for release were made by keeping the attack time fixed at its shortest at setting 7 and making a THD measurement at each release position. The measurements for attack were made by keeping the release time fixed at its shortest time at setting 7 and making measurements at each attack position. Each time a measurement was made the compressor was adjusted to achieve -10dB of gain reduction. As can be seen there is a sharp drop off in THD from up to release position 5 and a small reduction in THD with attack times slower than position 7.

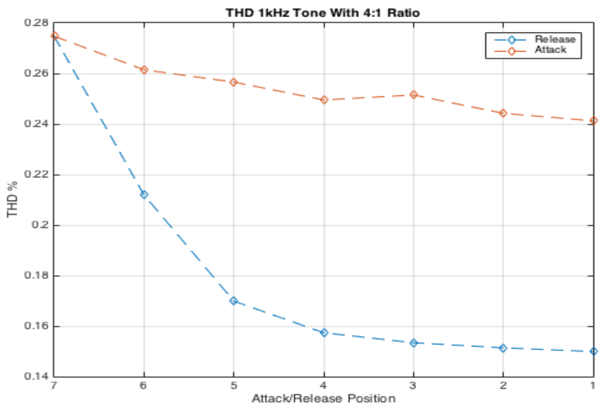

Figure 1. THD as a function of attack and release in 4:1 using a 1kHz tone

Figure 2 shows the same measurements made in all buttons. Note the much larger amount of THD in this setting but similar drop off in amount as the release and attack speeds are reduced.

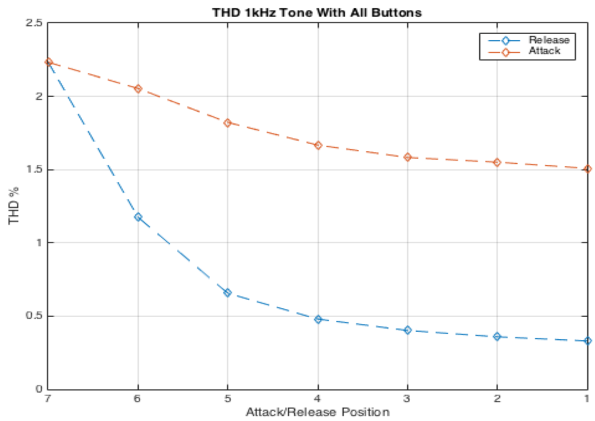

Figure 2. THD as a function of attack and release in all buttons using a 1kHz tone

Thus, it was hypothesised that the use of a fast release time (i.e. high numerical position) and the all buttons mode would result in a perceptually distorted vocal that would also be perceived as the most aggressive by the listener.

The THD measurements for the settings used in listening experiment one can be seen in Table 3 where the effect the attack and release controls and the all buttons mode has on non-linearity can be clearly observed.

Setting	THD %
A3R7 All	1.58
A1R7 All	1.51
A3R5 All	0.54
A1R5 All	0.50
A3R7 Four	0.25
A1R7 Four	0.24
A3R5 Four	0.17
A1R5 Four	0.16

Table 3. THD measurements made using a 1kHz tone and the time constants and ratios used in listening experiment 1

5 Listening Experiment 1 Method

To test the hypothesis a subjective listening test was devised using the Web Audio Evaluation Tool (WEAT) which made use of the Audio Perceptual Evaluation (APE) method. Stimuli were created by processing the vocal from two separate rock songs with a hardware 1176 using the attack/release combinations mentioned previously. To limit the number of stimuli the amount of compression was limited to one amount which was chosen to be -10dB of gain reduction. Ciletti et al. note that in order to best assess the sonic signature of a compressor it is advisable to use the device in a heavy state of compression [9]. Furthermore, the use of heavy compression in rock vocals is common place, particularly when aiming for an aggressive sound quality. The amount of gain reduction was measured to show an average of -10VU on the gain reduction meter. The compressed vocals were then mixed back into the audio tracks and levelled matched to -23 LUFS. In addition, a mix making use of the uncompressed vocal was used to create a total of nine stimuli per song.

Listeners were presented the stimuli on four separate screens of the listening test (two per song) where they were asked to rate the amount of perceived distortion on two screens and the amount of perceived aggression on the remainder. Scales on the interfaces were labelled from least distorted to most distorted and least aggressive to most aggressive and were measured on a 0-1 scale. Participants were not instructed explicitly what aggressive meant as the experimenters wished to avoid training the listeners with the experimenters' interpretation of this subjective descriptor. The order of the audio and screens were randomized to prevent bias and the test was carried out by 17 expert listeners in a controlled environment using Sennheiser HD650 headphones on iMac computers.

5.1 Results and Discussion for Experiment 1

The results from the listening test can be seen in Figure 3 which shows the mean result for the descriptor aggressive with a 95% confidence interval for both songs and all time constant settings tested. As can be seen there is little difference between the time constant settings for both the ratios tested but there is difference between the uncompressed material, the 4:1 ratio and the All buttons mode. It is worth noting the two all buttons modes which measured highest for THD (see Table 2 for THD results) are not rated any higher than the other two all buttons settings. Inspection of FFT plots suggest this is a result of the even order harmonics remaining fairly consistent in level across the four settings while the odd order harmonics are attenuated as attack and release are slowed, this results in a lower THD measurement which evidently does not result in a perceptually less aggressive sonic signature. It should be added, many of the participants reported the difference between some of the stimuli was small and they found the test to be challenging, therefore the effect of listener fatigue should be kept in mind.

The ratings for distortion are illustrated in Figure 4 where a similar trend is visible. Once again, there is difference between the ratios and the uncompressed material but no difference between the different time constant settings for the two ratio settings.

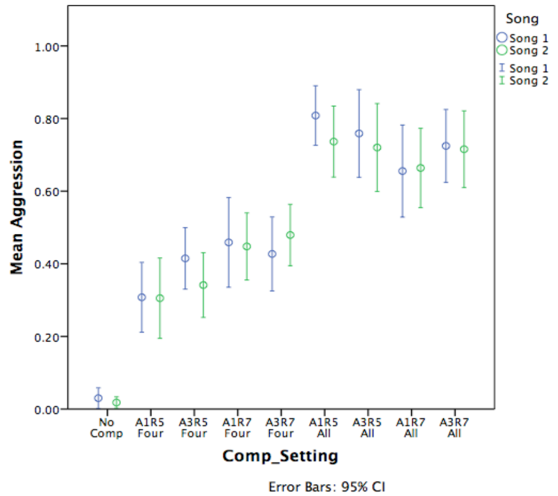

Figure 3. Aggressive results from the first listening experiment

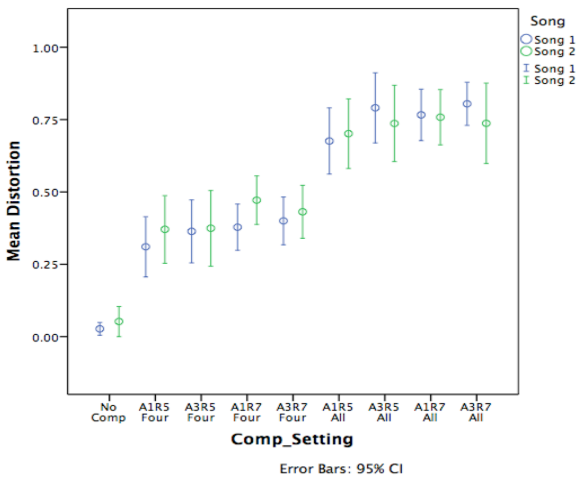

Figure 4. Distortion results from the first listening experiment

Audio features pertaining to noise-like properties of sound (Roughness and Zero Crossing Rate) were extracted from the vocal tracks using MIRtoolbox for Matlab [10] and are presented in Table 4. The results for roughness show the feature increases in value between the uncompressed audio and both ratio settings and also between 4:1 and all buttons mode.

Within the time constant settings for each ratio the results with the release time set to 7 are the highest and this is in the main commensurate with the THD results shown in Table 3. The similarity in results within the ratio settings for roughness may be another reason why listeners rated the time constant settings similarly despite variation in THD. The values for zero crossing rate (ZCR) are less revealing with no clear pattern in the results emerging apart from an increase in ZCR when using compression.

	Roughness		ZCR	
Setting	Song1	Song2	Song1	Song 2
No Comp	33.73	26.84	1887.92	1676.40
A1R5Four	99.12	106.58	2909.15	2155.41
A1R7Four	129.12	130.46	2915.28	2123.67
A3R5Four	98.97	102.17	2579.37	2166.41
A3R7Four	128.7	130.65	2484.85	2125.73
A1R5All	202.85	236.18	2966.41	2053.57
A1R7All	212.88	241.84	2850.03	2055.71
A3R5All	199.26	232.14	2881.21	2083.53
A3R7All	209.87	247.17	2953.82	2067.16

Table 4. Roughness and ZCR features extracted from the vocal material used in test one.

5.2 Statistical Analysis of Results of Experiment 1

A two way repeated measures ANOVA was run to determine the effect of compression settings and the interaction effect of the two songs and compression settings on perceived distortion. Mauchly's test of sphericity indicated that the assumptions of sphericity had been violated for the two-way interaction between the song and settings $\chi^2(2) = 73.13$, $p = .001$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.580$). Mauchly's test of sphericity indicated that the assumptions of sphericity had not been violated for the effect of settings $\chi^2(2) = 48.45$, $p = .081$.

Simple main effects were run and showed there was no statistically significant two-way interaction between the songs and settings on perceived distortion, F (8,128) = 0.648, $p = .653$. There was however a statistically significant effect of settings on perceived distortion, F (8,128) = 50.97, $p < .001$. Post hoc analysis with a Bonferroni adjustment showed the mean distortion scores for the 4:1 and all buttons settings were statistically significantly higher than the scores for no compression ($p <.001$). In addition, the mean distortion scores for the all buttons settings were statistically significantly higher than the scores for the 4:1 ratio settings ($p <.001$). Within the four-different time constant settings used for both 4:1 and all buttons there was no statistical significance.

A second two way repeated measures ANOVA was run to determine the effect of compression settings and the interaction of the two songs and compression settings on perceived aggression. Again, Mauchly's test of sphericity indicated that the assumptions of sphericity had been violated for the two-way interaction between the song and settings $\chi^2(2) = 53.99$, $p = .028$ thus a Greenhouse-Geisser correction was applied ($\varepsilon = 0.531$). Mauchly's test of sphericity indicated that the assumptions of sphericity had not been violated for the effect of settings $\chi^2(2) = 27.98$, $p = .081$.

Simple main effects were run and showed there was no statistically significant two-way interaction between the songs and settings on aggressive sound quality, F (8,128) = 0.301, $p = .886$. There was however a statistically significant effect of settings on aggressive sound quality, F (8,128) = 69.26, $p < .001$ suggesting settings have a statistically significant effect on an aggressive sound quality. Post hoc analysis with a Bonferroni adjustment showed the same statistical significance between no compression and the two ratio settings as reported previously for distortion. Again, there was no statistical significance within the four-different time constant settings used for either 4:1 or all buttons, meaning in the current study the different time constant settings have no significant effect on the perception of distortion or an aggressive sound quality.

The mean scores for aggressive and distortion were analyzed to assess if there was statistically significant correlation between the scores. Both variables (aggressive and distortion) for both songs were normally distributed, as assessed by a Shapiro-Wilk's test (p >.05) thus the variables were investigated for correlation. A Pearson's product-moment correlation was run to determine the relationship between perceived aggressive and distortion scores and results show there is a strong correlation between the mean scores for aggressive and distortion which is statistically significant for song one (r =.960, n =9, p =.001) and song two (r =.983, n =9 p =.001). A scatter plot of the mean scores for aggressive and distortion for both songs is illustrated in Figure 5 where the correlation between the two can be clearly observed.

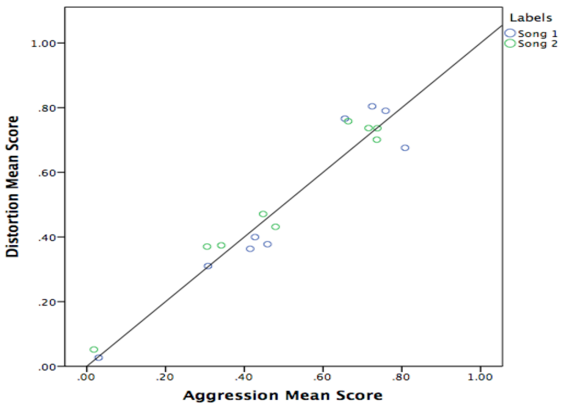

Figure 5. Scatter plot for aggression and distortion mean scores

Correlation between the aggressive scores and the roughness features extracted from the vocal files was investigated by running a Pearson's product-moment correlation. The results show a strong correlation between roughness and aggressive which is statistically significant for song one (r =.968, n =9 p =.001) and song two (r =.962, n =9 p =.001).

6 Listening Experiment 2 Method

The previous test demonstrated vocals compressed with settings measured to have greater than or equal to 0.5% THD were rated as being the most aggressive sounding. However, it could be argued the timing behavior of the 1176, particularly when working in all buttons mode, is playing a role in the result. Therefore, a second test was devised which aimed to decouple distortion and timing behavior and answer whether distortion, timing behavior or a mixture of both were the key components in the creation of an aggressive vocal sound quality. The experiment made use of the APE listening test interface and had participants rate the vocal tracks of three separate songs on the aggressive quality of the vocals. The two songs used in the previous experiment were utilized again as well as a third new rock song which was added to give the results more validity over a wider range of test scenarios. The order of the audio and screens were randomized to prevent bias and the test was carried out by 18 expert listeners in a controlled environment using Sennheiser HD650 headphones on iMac computers.

During the previous experiment, it was found the time constant settings had no significant effect on an aggressive sound quality therefore the vocal tracks were compressed with the hardware 1176 using only the A3R7 time constant (measured highest for THD) and in 4:1 and all buttons ratio modes. In addition, the vocals were compressed with the Klanghelm DC8C software compressor using settings that emulated the timing behaviour of the 1176 in both ratios and set to measure 0% THD. The timing behaviour was emulated by feeding the hardware 1176 and the software compressor a tone burst and adjusting the parameters of the software compressor until the software closely resembled the timing curve of the 1176 in both settings. See previous work by the authors where the tone burst method is used and discussed in more detail [11]. While this method did not allow for exact matching of the 1176's timing curve it did create results that were very similar and appropriate for this study. A more robust method could make use of a specifically designed software compressor algorithm that allows the experimenter to simply turn on and off distortion but this would require close modelling of the 1176, which was beyond the scope of the current study.

6.1 Results and Discussion: Experiment 2

The results from the second listening experiment are depicted in Figure 6 which represents the mean result for the descriptor aggressive with a 95% confidence interval for all three songs and all time constant settings tested.

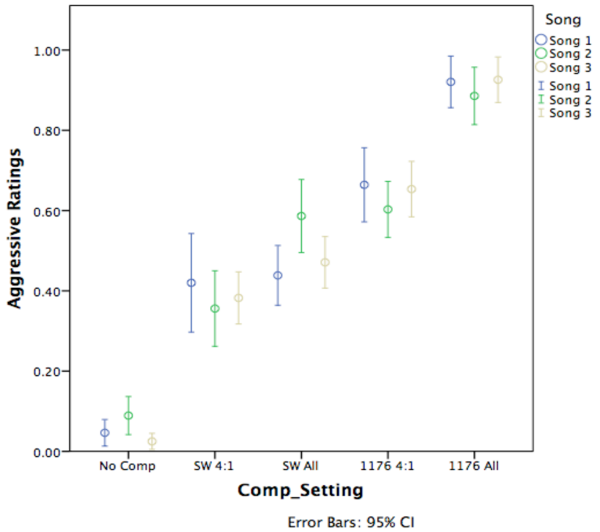

Figure 6. Aggressive results from the second listening experiment

Looking at the chart there is overlap between the scores for SW 4:1 and SW All for songs one and three and overlap between SW All and 1176 4:1 for song two. However, it is apparent the 1176 all buttons setting has been rated as the most aggressive for all three songs and the clean software emulation measured to have 0% THD does not score remotely as high as the 1176 all buttons mode. Thus, the results suggest compression activities that generate audible distortion are needed for the most aggressive vocal sonic signatures.

6.2 Statistical Analysis of Results of Experiment 2

A two way repeated measures ANOVA was run to determine the effect of compression settings measured to have or not have distortion and the interaction effect of the three songs and compression settings on an aggressive sound quality. Mauchly's test of sphericity indicated that the assumptions of sphericity had been violated for the two-way interaction between the song and settings $\chi^2(2) = 71.82$, $p = .001$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.578$). Mauchly's test of sphericity indicated that the assumptions of sphericity had not been violated for the effect of the settings $\chi^2(2) = 7.45$, $p = .593$.

Simple main effects were run and showed again there was no statistically significant two-way interaction between the songs and settings on aggressive sound quality F (8,136) = 0.208, p = .081. There was however a statistically significant effect of settings on an aggressive sound quality, F (4,68) = 181.722, $p < .001$ suggesting the settings used have a statistically significant effect. Post hoc analysis with a Bonferroni adjustment showed the mean aggressive scores for all compressed settings were statistically significantly higher than the scores for no compression ($p <.001$). The scores for both the 1176 settings were statistically different from one another ($p <.001$) but the scores for both the software settings were not statistically different ($p=.57$). This indicates the faster timing behaviour of the SW ALL setting, which was emulating the timing curve of the 1176 in all buttons, has little additional effect over the SW 4:1 setting in the creation of an aggressive vocal sonic signature. The scores for both the 1176 settings were statistically higher than the scores for both the software settings ($p <.001$). This indicates that while a clean fast acting compressor can give a vocal a more aggressive sound quality than the uncompressed audio, compression settings that impart audible distortion are required for the most significant effect.

7 Conclusions

This paper has shown professional engineers use the subjective descriptor "aggressive", when describing the sound quality of the UA 1176 compressor, to relate to compression techniques that distort and colour the signal and additionally techniques which reshape the transient portion of audio material. These techniques may be related, due to the distortion process having an effect on the transient portion of audio. Additionally, it can be argued sharp transients have an aggressive sound quality so respondents may be relating the attenuation of transients to the distortion process but accentuation of transients to its own technique. More work needs to be done to answer these questions empirically.

The first listening experiment demonstrated there is a strong positive correlation between the subjective scores for distortion and aggressive when rating the same audio stimuli in a controlled listening experiment. It was also shown that compression settings measured to have 0.5% THD and above were rated as both the most distorted and most aggressive but there was no significant difference between settings measured to have more than 0.5% THD. Meaning, in this current study listeners could not discern any noticeable difference in perceived distortion or aggression between audio measured between 0.5% and 1.58% THD. It was also illustrated that the various time constant settings used in the experiment, which were gleaned from common settings used in the industry, had no significant effect on the perception of distortion or aggressive sonic signatures. It should be added that some listeners reported in the first experiment they found it very difficult to hear any difference between some of the stimuli and although they could discern there were some group differences in the stimuli it was difficult to hear the differences between certain individual stimuli. This appears to be represented in the listening tests results and the charts in Figures 3 and 4. Finally, the experiment revealed a strong correlation between settings rated as aggressive and the audio feature roughness suggesting this feature may have a role in measuring or predicting the aggressive descriptor used by engineers.

The second listening experiment revealed that compression which imparts distortion onto the program material is needed to achieve the most aggressive sound qualities. It appears fast compression with no distortion (as emulated with the clean software compressor) can have an effect on aggressive sound qualities but the effect is not nearly as large as when using fast acting compression and distorted artefacts.

Both experiments indicated there was no interaction effect between the songs used and the compression settings thus it appears the choice of songs used had little bearing in the results and the findings from these two experiments should translate to other songs in the same hard rock genre. However, this needs further investigation with more different songs to be certain. It is not clear however how the results would transfer to non-vocal program material or music that is not in the hard rock genre.

8 Further Work

The authors of the paper hope to extend the qualitative study discussed in section 2 to include more engineers and producers thus giving the results greater validity. Further work could also be carried out to ascertain how much of a difference listeners can hear between different attack and release times when compressing the vocal in a music mix. There are many texts that suggest setting a compressor's attack and release within specific ranges for different program material but can listeners discern any difference between timings set within these ranges? For example, can listeners truly tell a difference in release times on a rock vocal in a mix between 150-300ms? Research questions could ask if varying attack and release within a particular range are perceived as being significantly different from one another and this could be tested using the paired comparison method. The results from such a study could help recording engineers speed up their workflow and could also be used by developers of automated mixing technology to make their compression algorithms more effective.

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