Audio Engineering Society

Convention Paper

Presented at the 136th Convention
2014 April 26–29 Berlin, Germany

Hyper-compression in Music Production: Listener Preferences on Dynamic Range Reduction.

Robert W. Taylor[1] and William L. Martens [2]

[1]Faculty of Science and Information Technology, The University of Newcastle, NSW, Australia.
robert.w.taylor@uon.edu.au

[2] Faculty of Architecture, Design and Planning, The University of Sydney, NSW, Australia.
william.martens@sydney.edu.au

ABSTRACT

Achieving ‘loud’ recordings as a result of hyper-compression is a prevailing expectation within the creative system of music production, sustaining a myth that has been developing since the mid-twentieth century as a consequence of the ‘louder is better’ paradigm. The study reported here investigated whether the amounts of hyper-compression typical of current audio practice produce results that listeners prefer. The experimental approach taken in this study was to conduct a subjective preference test requiring listeners to make a forced choice between seven levels of compression for each of five musical programs that differed in musical genre. The presented seven versions of each musical program were carefully matched in loudness as the versions were varied in compression level, and so differences in loudness *per se* cannot account for the differences in preferences choices observed between musical programs. In addition, it was found that subject factors such as age group, and speculatively the amount of exposure to different genres, were of considerable influence on listener preferences.

1. INTRODUCTION

Since the 1950s, the commercial music industry has witnessed large increases in the relative level of sound recordings [1]. This shift was arguably predicated upon the established assumption that a ‘louder’ recording will invariably, by comparison, be preferable to most listeners [2][3]. This constellation of beliefs and practices is termed here the ‘*louder is better*’ paradigm.

This deeply entrenched paradigm draws upon two distinct considerations: Firstly, preferences may be due to the innate workings of human hearing, which displays a more linear frequency response at a higher sound pressure levels [4]. Secondly, louder music may engender a heightened psychophysical response [5][6]. These considerations have led artists and music companies to actively seek increases in recording levels, such that their product was relatively ‘louder’ than its competitors.

The arrival of the Compact Disc (CD) in the early 80s heralded a greater level of 'loudness' possible than with previous analog reproduction mediums [7]. Yet once the maximum level had been reached with this technology (0dBFS), a production method was employed to further increase *perceived loudness*; 'hyper-compression' [8]. This production method describes an excessive form of DRC characteristically present in most modern commercial music [2].

Reducing the dynamic range of signals enables an RMS level increase without clipping, resulting in a higher average output that typically sounds louder. Consequently, new ways with which to reduce dynamic range through Dynamic Range Compression (DRC) were employed across a wide range of program material, originating from radio broadcast. The introduction of digital processing in the 90s delivered even more effective ways to manipulate the dynamic range of signals.

Designed to achieve the loudest sounding music product, hyper-compression pushed the physical limitations of digital media in a never-ending quest for 'loudness'. Once one artist had reached a new level of 'loudness', all others had to follow so when comparisons where made between recordings, one was seen as softer and in a sense '*inferior'* [3]. A chain of events unfolded and there was seemingly no way of reversing the trend [9]. Many adverse effects from the hyper-compression process have been extensively reported in studies [2][10][11][12]. These include consequences such as distortion, the atrophy of musicality, listener fatigue. Could this lead to a significant movement against the practice worldwide?

'Loudness' in the creative system of music production however, could also be considered as an aesthetic *choice* functioning *within* the 'louder is better' paradigm. Accordingly, it can be argued that 'loudness' has transformed over time from a phenomenon considered solely as a form of 'competition' in the marketplace for music. It can be viewed as a production *aesthetic* in response to the development of digital technology. The technology and 'loudness' itself signified a distinct transformation in the representation of some genres of music. Genres such as classical and jazz would remain entrenched in a static form. Other genres such as EDM (electronic dance music) became defined by the digital technology from which the music emerged [13]. A question is then posed: Is hyper-compression justified in the creative process of some genres and not others, and to what extent?

Within the creative system of music production, the continued use of hyper-compression by audio practitioners should suggest that there are defensible aesthetic or creative justifications for employing hyper-compression. These justifications should be in line with listener expectations. Surprisingly, despite this now dominant paradigm in creative music production, there exists a conspicuous lack of rigorous investigation in this area. From this perspective, it is found that listener preferences remain relatively unknown. Is the *average* listener aware of the significantly reduced dynamic range of the popular music they generally listen to? The answer would most likely be no. However, given the chance to choose an alternative, what would they prefer?

To ascertain these preferences is surprisingly difficult. There are myriad factors that come into play with this type of analysis, such as the listener's predilection and demographic bias towards particular types of music. Another major factor could also be the cultural and creative models of the individual genres of music as mentioned, i.e., what some listeners, compared to others, *expect*. The way people listen to music has also encountered a shift since the introduction of personal media players in the last decade. In particular, the use of small satellite speakers that accompany computers and the burgeoning use of headphones directly impacts the method and quality of delivery [14][15].

The primary aim of this study was to determine the degree of compression preferred by listeners in commercial music. Its secondary aim was to determine effective methodologies for further studies. The current preference test was performed to discover whether listeners would a) discriminate between differing compression values and b) be in consensual agreement in their preferences over five genres of music (*pop*, *rock*, *dance*, *acoustic* and *classical*). To represent a typical modern listening scenario, the musical stimuli were presented using small satellite speakers within an acoustic environment similar to an average living room. For four of the five genres tested, stimuli were sourced from un-compressed multi-track masters. The *classical* stimulus was processed as a pre-mixed stereo recording. Subjects were presented with a choice between seven degrees of compression magnitude, ranging from no compression to extreme compression. In addition, the seven versions of each musical program were carefully matched in loudness as the versions were varied in compression level, so preferences choices observed between musical programs could not depend upon loudness differences between stimuli.

2. METHOD

2.1. Stimulus generation and preparation

2.1.1. Musical stimuli selection and criteria

Five musical pieces representing the five genres (*pop*, *rock*, *dance*, *acoustic* and *classical*) were chosen according to instrumentation, tempo and compositional structure typical of each genre. *Classical* was included as a type of 'control' stimulus, since the preference for less compression was expected for the classical music genre when compared to other genres. It was reasoned that this control condition would assist in determining whether subjects were able to discriminate between different amounts of compression. A criterion for the selection of the music stimuli was established according to instrumentation, tempo and compositional structure typical of each genre. The stimuli were chosen in accordance with these criteria. The genres represented were as follows:

Rock: Live drums, electric bass, electric guitar, slide guitar, acoustic guitar, lead vocal and multi-layered backing vocals. A tempo of 120 BPM (beats per minute).
Dance: Sampled electronic drums, synth bass, synthesisers, sound FX, lead vocal and multi-layered backing vocals. A tempo of 128 BPM.
Pop: A mixture of electronic and live sampled drums, synth bass, electric guitar, electric piano, sampled strings, synthesisers, lead vocal and multi-layered backing vocals. A tempo of 105 BPM.
Acoustic: Acoustic piano, acoustic guitar and singular lead vocal. A tempo of approximately 90 BPM.
Classical: Violins, violas, cellos, basses (stringed orchestra) and violin soloist. No vocal present. A tempo of 'allegro molto' (lively and moderate).

The selected musical programs were the following:

- Pop: 'Shadows Always Waiting (Part1)' by Black Dove.
- Dance: 'Keep It Natural' by Cosima De Vito. Taylor Square remix.
- Rock: 'You're Just Too Young For Me' by Celebrity Drug Disasters.
- Acoustic: 'By Your Side' by Jimmy Somerville.
- Classical: 'The Lark Ascending' by Vaughn Williams. Conducted by Neville Marriner.

2.1.2. Equipment

The musical stimuli were processed using the audio system described below:

- Logic Audio (9.1.8).
- Apple MacPro 2.4GHz dual quad-core computer.
- Mark of the Unicorn 1296 audio interface.
- Apogee Mini-DAC converter.
- Genelec 1031A powered loudspeakers.
- Plug-ins supplied within Logic Audio and various Waves plug-ins included in the 'Mercury' pack.

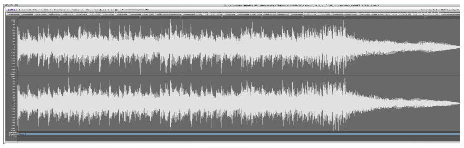
2.1.3. Processing of music stimuli

Multi-track masters were sourced and mixed to approximately the same mix bus output level with no mix bus processing (mastering) present. The exception was the classical recording as no mix bus processing was present. The recordings were edited to segments with a length of between 19 and 31 seconds that included the predominant musical theme of the composition such as the chorus or main melody. Typical processing of individual elements was performed during the mixing including equalization, compression, reverb and delay. All mix masters were then peak normalized to 0dBFS. The five musical stimuli were further processed ('mastered') using plug-ins supplied for this specific purpose in the Logic Audio software package; 'Multipressor' (multi-band compressor) and 'Adaptive Limiter' (look-ahead brick-wall limiter). The aim was to represent a typical mastering strategy that could establish a reduction in dynamic range known as 'hyper-compression'.

Multi-band compression was applied first and then limiting as is the normal practice in mastering. The parameters for 'Multipressor' are based on a preset supplied called 'Linear medium MP' designated for this type of processing (Appendix A). The parameters for 'Adaptive Limiter' were developed from initialised settings to achieve results common of extremely heavy 'brick-wall' limiting at maximum (Appendix B). The final 'Gain' level of 10dB achieved the target amount of hyper-compression that to a trained ear was noticeably distorted and comparable to the type of extreme hyper-compression that has been criticised in [10][11][12].

The seven levels of compression exhibited by the processed stimuli represent a gradual increase from unprocessed to extreme hyper-compression (Figure 1).

The highest compression level (7) is typical of the kind of commercial recordings that demonstrate an extremely high degree of reduced dynamic range and audible non-linear distortion. The processing was repeated for all five musical excerpts resulting in a total of 35 stimuli for the experiment.

i) 

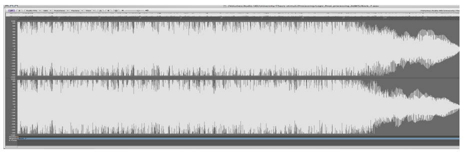
ii) 

Figure 1: The waveforms of these two stimuli illustrate the opposing extremes in compression levels; i) the unprocessed original mix (level 1) and ii) the hyper-compressed 'mastered' version (level 7).

2.2. Stimulus calibration of loudness

2.2.1. Initial signal leveling and loudness matching

As the compression magnitude increased over the seven stimuli, so was the RMS of the signal (by as much as 9dB), causing an increase in perceived loudness. It was planned to compare multiple versions of each of five musical programs specifically in terms of the preferred amount of compression for each. Therefore, it was important for these different versions to be very similar in perceived loudness. Otherwise, preferences could be prejudiced toward the auditory attributes associated with loudness and not the perceptual cues associated with compression. Accordingly, all stimuli were initially loudness matched using an ITU-R BS-1770 compliant loudness meter [16]. The NuGen Audio VisLM-H loudness meter was utilised and all stimuli were normalised to the target Loudness Unit (LU) level of -23LKFS with an accepted tolerance of ± 1LUFS [17].

2.2.2. Point of subjective equality for loudness

Despite the fact that predicted loudness was matched using a computer-based analysis of the audio signals, the ground truth for perceived loudness matches could not be established except through listening tests. The method used here employed via a staircase procedure designed to track the point of subjective equality (PSE) for loudness between a fixed standard and a variable comparison stimulus. Accordingly, adjustments between 0-2dB were made to corresponding stimuli (Appendix C) in order to match the loudness of all stimuli to that of a standard stimulus.

3. METHODS

3.1. Equipment

PCM audio files were played from hard disc using the standard audio conversion hardware of an Apple MacBookPro 17" laptop computer (2011). Reproduction was via Harman Kardon Soundsticks III 'satellite' loudspeakers, typical of loudspeakers designed for use with computers. The audio files were triggered via a USB MIDI keyboard controller.

3.2. Reference level for loudspeakers

The playback level for the stimuli was calibrated as per monitoring requirements outlined in [18]. 500Hz – 2kHz band limited pink noise at -20dBFS was replayed via the loudspeaker system and volume adjusted to an output SPL of 76 dB (re: $20\,\mu N/M^2$) at the listener position using slow reading (1 s integration time) and C weighting, per speaker. This corresponds to requirements for a monitoring room of less than 457 cubic meters as used in the experiment. SPL was measured using a Bruel and Kjaer model 2250 sound level meter. The reading was measured at the position of the center of the head of the listener, seated in position and oriented towards the speaker under calibration.

3.3. Subjects

The 30 subjects who participated were separated into groups according to three main demographic criteria: gender (25 male to 5 female), musical training (20 trained to 10 untrained listeners) and age (which ranged from 25 to 68 years of age). Subjects were screened informally for any obvious hearing impairment. Trained subjects were those considered to either have professional experience in audio production or extensive musical training. Untrained subjects had neither of the above.

3.4. Listener preference task

The experiment took place in the recording area of an audio studio at the University of Sydney, providing an acoustic environment similar to that of a furnished household lounge room or bedroom. Subjects were required to choose between the seven stimuli presented. The first version (labeled "1") represented no compression. Subsequent versions were arranged in ascending order, ending with the version (labeled "7") representing hyper-compression. Subjects were not informed of what particular processing had been implemented on the stimuli and asked to choose which version was preferred. Subjects were also asked to take into consideration the genre of music, and to consider which of the progressive increments in compression sounded most *appropriate* with respect to genre.

The stimuli were presented to the subjects via a USB MIDI controlled keyboard with the corresponding seven stimuli assigned to individual sequential white keys and labeled one to seven. The software sampler ESX24 was used as the playback engine with the five groups of seven stimuli loaded into individually labeled sample sets and assigned to the appropriate keys. The length of playback of the stimuli would depend on the length of time the key was depressed enabling the subjects to hear as much or as little of the stimuli as needed to make their decision. Subjects could alternate between any stimuli at will. This enabled decisions based on instant recognition of the different levels of processing as opposed to memory. Once a decision was made in a genre, subjects were asked to record their preference on a written questionnaire. This process would be repeated until all five preferences were determined and recorded.

4. RESULTS AND ANALYSIS

The experimental task required a forced preference choice to be made between seven levels of compression. Three non-parametric tests have been applied to the discrete-valued data collected from these experiments:

- Exact Binomial Test for the random likelihood of results (Figure 2 shows distributions).
- Kruskal- Wallis test for the homogeneity among listener preferences.
- Wilcoxon test for the difference between groups.

The Exact Binomial Tests confirm that Pop and Classical showed significant different preference results. The Kruskal-Wallis and Wilcoxon tests uncover differences between demographic groups.

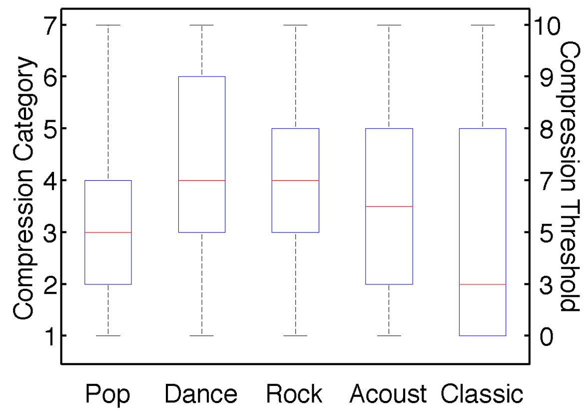


Figure 2: Subject preference (Appendix D) A boxplot showing interquartile ranges and medians (red lines).

Out of the 30 subjects that undertook the listening test, one subject withdrew from the experiment due to not feeling well at the time. Therefore the results reported were based on the remaining 29 subjects.

4.1. Exact binomial test

A binomial probability distribution was calculated for the 29 subjects and 7 responses to ascertain the probability of the null hypothesis (H_0) that responses were purely random. The subject preference response tally was compared to the binomial probability distribution. Preference response counts of either 0 or ≥ 8 indicate a probability of < 0.05. H_0 is rejected for *classical* ($p = 0.0005$) and *pop* ($p \leq 0.05$) genres with respective responses of 11 for option 1 compression magnitude, and 9 for option 3. *Classical* had the largest recorded tally for a particular genre. The preference tallies for the remaining genres *dance*, *rock* and *acoustic* showed no strong pattern and did not allow H_0 to be rejected.

Were subjects actually able to discriminate between processing magnitudes and report meaningful responses? The reported result for *classical* was expected. This indicates that subjects were probably able to perceive the difference between compression values and report a meaningful response. *Pop* could also suggest listeners were able to discriminate between compression levels and proved to be the only other genre where a statistically significant consensus was present in subject responses. One possible argument is that *pop* music, being the most commercially prevalent of all music genres and the most common to listeners, has established an entrenched cultural model like *classical*.

The other genres *dance*, *rock* and *acoustic* did not provide results that could allow H_0 to be rejected and responses appeared more evenly dispersed. This could suggest that subjects either could not discriminate between compression values or have diverse personal preferences concerning these genres. Hence no consensus could be reached. Further research is needed in this area. There was however an interesting consensus in what subjects *did not like* in both *dance* and *rock*. Dance scored only 1 preference response for no compression ($p < 0.06$) and could indicate that at least *some* compression is preferred. Similarly, *rock* scored only 1 response for compression magnitude 7, indicating that the maximum amount of 'hyper-compression' is disliked. *Acoustic* displayed the most mixed responses which were very evenly dispersed. This could indicate that subjects had less cultural familiarity with the genre to base their preference on than *classical* and *pop*. Exposure to and subsequent cultural familiarity to genre could certainly be a defining factor in compression preferences even if the listener is not noticeably aware of the actual process. Furthermore, these initial results for *pop* displayed a preference for moderate dynamic range reduction and certainly could not be described as *hyper-compression*. This is at odds with nearly every commercial pop release.

4.2. Kruskal-Wallis test

A Kruskal-Wallis test (analogous to a one-way analysis of variance – ANOVA) was performed. The test revealed a two-tailed p-value of 0.021 rejecting H_0 that the subjects came from the same population. Further analysis of sub-groups was therefore warranted.

K (Observed value)	45.274
K (Critical value)	41.337
DF	28
p-value (Two-tailed)	0.021
alpha	0.05

Table 1: The results for the Kruskal-Wallis test ($p = 0.021$) rejects the H_0 that the subjects came from the same population.

4.3. Wilcoxon (Mann-Whitney) test

The Wilcoxon (Mann-Whitney) rank-sum test was employed to test for differences of proportion between subject groups by assessing whether their population mean ranks differ. Significant differences were found in trained versus un-trained and age (≤ 30 - > 30) demographic sub-groups. The test could not be applied to gender due to the small number female participants (5 female to 25 male) making it difficult for any meaningful comparison.

4.3.1. Trained vs un-trained listeners

Subjects were divided into two groups defined by training. The first group contained 10 untrained listeners and the second, 19 trained. Each genre was tested for disparity between group responses.

Genre	Test Stat(z)	p(H_0)
Pop	4.26	0.0001
Dance	-0.045	0.6736
Rock	0.045	0.3264
Acoustic	1	0.1587
Classical	0.96	0.1658

Table 2: The Wilcoxon (Mann-Whitney) test for differences between trained versus un-trained listeners resulted in only one genre (pop) showing a significant difference.

Trained versus un-trained listeners indicated a significant difference in only one genre, *pop* with p = <0.0001, rejecting H_0 that there is no difference between groups as described in Table 2. This was in contrast to the other four genres. It could be suggested this demographic characteristic of *pop* is again a consequence of being the most commercially prevalent of all music genres and the most common to listeners.

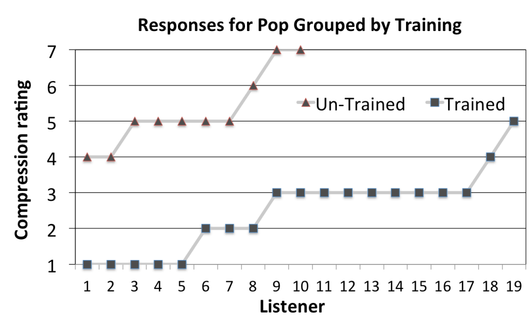


Figure 3: Illustrates the individual compression ratings of the 29 listeners separated into groups defined by training. Un-trained listeners showed a significantly higher preference of compression for *pop* than those that were trained.

When results were further analysed, it was evident from Figure 3 that untrained listeners prefer a higher amount of compression than those that are trained with this genre. Untrained listeners may be more conditioned to a higher magnitude of compression through constant exposure to hyper-compression and therefore could consider this as ‘normal’. In contrast, trained listeners could prefer a lower magnitude as a result of being trained as ‘active’ listeners. It is worth noting that the trained listeners provided all of the 9 preferences for compression level 3. Therefore, this group is directly responsible for the genre having a statistically significant consensus overall. Binomial probability distributions were then calculated for both groups individually. A preference count of 5 for compression magnitude 5 for untrained listeners indicates p=< 0.05, rejecting H_0 that responses were random. Likewise, A preference count of 9 for compression magnitude 3 for trained listeners also indicates p=< 0.05, rejecting H_0 as well. Therefore, there is a clear disparity between these groups in regards to *pop*. It further indicates that untrained listeners prefer a higher magnitude of compression. Regardless of this difference however, preferences for compression magnitude by either group are nonetheless lower than what could be described as hyper-compression.

A homogeneity of preferences for *classical* can possibly be understood from the culturally pre-determined standpoint of the genre. However, it is unclear why such a disparity exists only for *pop* and not other genres such as *dance* or *rock* that share a common link with widespread use of hyper-compression. Further research is needed in this area.

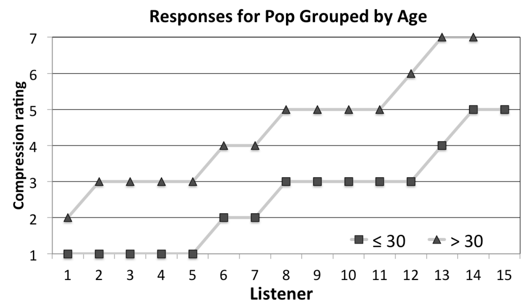
4.3.2. Subject age groups

Subjects were divided into two age categories representing an approximate 50/50 split with ‘Group A’ ≤ 30 years and ‘Group B’ > 30 years. Group A (15 subjects) contained a narrow age range of 25-30 defined as Generation Y in comparison to Group B containing a wider range from 31-68 (14 subjects) defined as Generation X and ‘Baby Boomers’.

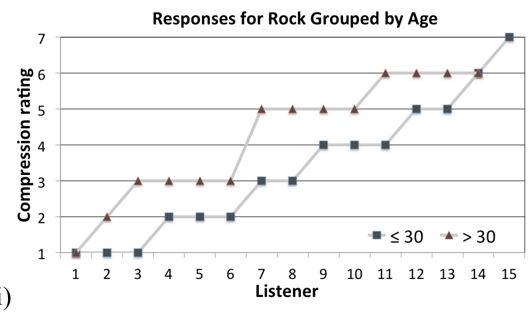
Genre	Test Stat(z)	p(H_0)
Pop	3.535129822	0.0002
Dance	0.698297249	0.2451
Rock	1.920317434	0.0274
Acoustic	2.182178902	0.0146
Classical	0.349148624	0.3669

Table 3: The Wilcoxon (Mann-Whitney) test for differences between two age groups of listeners resulted in three genres (*pop*, *rock* and *acoustic*) showing a significant difference.

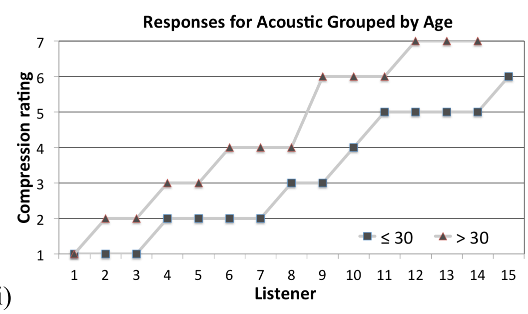
A significant difference between age groups was discovered for *pop* (p = 0.0002), *rock* (p = 0.0274) and *acoustic* (p = 0.0146) as described in Table 3. Both *classical* and *dance* indicated homogenous responses.



i)



ii)



iii)

Figure 4: Illustrates the individual compression ratings of the 29 listeners separated into groups defined by age. All three genres i) *pop*, ii) *rock* and iii) *acoustic* depict the age group > 30 to have overall higher compression magnitude preference.

When further analysed, all three genres exhibited preferences for higher compression magnitude with subjects > 30 years old, in contrast to the ≤ 30 year old group (Figure 4). It can be assumed from these results that age has some bearing on listener preferences of these genres. *Pop* displayed the largest difference between groups. A factor that may have contributed to this is Group B (> 30 years old) contained the highest amount, by proportion, of un-trained listeners (Figure 5). The result reported in the previous demographic analysis (un-trained listeners preferring higher compression magnitudes) with this genre may have had some influence.

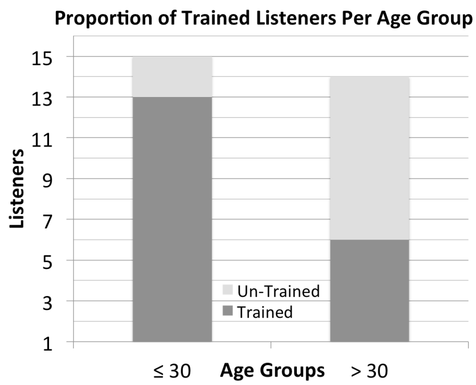


Figure 5: A high proportion of untrained listeners belonged to Group B (> 30 years old). This may have had some influence in *pop* recording the highest disparity between age groups.

Why age would have such a broad impact on preferences is unknown and calls for further research. However, if one were to make an initial speculation, it is tempting to say that the effect is due to the length and type of exposure to hyper-compression. This could account for Group B (> 30 years old) preferring a higher degree of compression. Accordingly, Group A (≤ 30 years old), were exposed to a period where hyper-compression seems to have slightly decreased since 2005 [19]. Indeed, this group might be part of a generation that is actively rejecting hyper-compression and more educated on the topic. Alternatively, the observed preference for higher compression in this group might be due to age-related hearing loss. At this time it is mere conjecture and could be the topic of another study.

5. CONCLUSION AND DISCUSSION

The aim of this study was to determine the degree of compression preferred by listeners in commercial music. Its secondary aim was to determine effective methodologies for further studies. A listening test was performed to discover whether listeners would a) discriminate between compression values, b) reach a consensus on preferences and c) exhibit preferences influenced by genre. Five genres of music (*pop*, *rock*, *dance*, *acoustic* and *classical*) were chosen to represent a broad range of popular styles of music. *Classical* was included as a 'control' and preferred compression levels were expected to be lowest for this genre. Subjects were presented with a choice between seven degrees of compression magnitude, ranging from no compression to extreme hyper-compression. They were required to choose which compression level was preferred with respect to genre.

A statistically significant result was achieved for both *classical* and *pop*. *Classical* (the control) achieved the strongest preference consensus indicating that listeners were probably able to discriminate between compression levels. *Pop* could also suggest listeners were able to discriminate between compression levels and proved to be the only other genre where a consensus was reached. It was suggested that *pop* music, being the most commercially prevalent of all music genres and the most common to listeners, could have established an entrenched cultural model like *classical* that enabled this consensus. The results for the remaining three genres *dance*, *rock* and *acoustic* could not provide significant results and preferences were more evenly dispersed. This could indicate that subjects had less cultural familiarity with these genres to base their preference on than *classical* and *pop*. A possible explanation was suggested. Exposure to and subsequent cultural familiarity to genre could certainly be a defining factor in compression preference. Furthermore, the compression preference for *pop* indicates a moderate dynamic range reduction and certainly could not be described as *hyper-compression*.

Further analysis was undertaken to examine differences in proportion between subject demographic sub-groups. Significant differences were found in trained versus un-trained and age (≤ 30 - > 30) groups. Trained versus un-trained listeners indicated a significant difference in only one genre, *pop*. This was in contrast to the other four genres. It was evident that untrained listeners prefer a higher amount of compression than those that are trained concerning this genre. It was suggested this could be a result of constant exposure to hyper-compression and without production experience, considering this as 'normal'. Trained listeners by contrast could prefer a lower degree of compression as a result of being trained as 'active' listeners. It was suggested this demographic characteristic could again be a consequence of *pop* the most commercially prevalent of all music genres and the most common to all listeners.

A significant difference between age groups was discovered for *pop*, *rock* and *acoustic.* Responses in both *classical* and *dance* were independent of age. Further analysis indicated that older listeners in the > 30 age category exhibited preferences for higher compression magnitude than the younger Gen Y ≤ 30. *Pop* displayed the largest difference between groups. A factor that may have contributed to this is the > 30 age category contained the highest amount, by proportion, of un-trained listeners. However, why age would have such a broad impact on preferences in unknown and could be the topic of another study. In conclusion to this demographic analysis, the two sets of data proved to be interconnected. This certainly confounded analysis affording no easy way to separate the data and pinpoint certain causes. Additionally, gender was unable to be included due to the small number of female participants. It is therefore suggested that the use of balanced subject groups would make this comparison process easier and more conclusive in future studies.

Considerations concerning methodology revolve around the type of stimulus and perceptual cues presented. It was thought that one sample per genre would not allow a generalisation to be made. Would another stimuli of the same genre repeat the results of the first? Within the confines of this study it is doubtful. It therefore begs the question of what *are* the dominant perceptual cues. Preferences on *classical* were so strong that most classical pieces would probably yield similar results. The stimulus used for this genre exhibited a large dynamic range before any processing, as is the case with much of the music of this genre. Incorporating another genre similar to classical, such as *jazz* would help confirm this assumption. All other samples initially had relatively constant dynamic range over time by comparison to the classical stimuli. It was therefore assumed that the other musical samples didn't show enough initial dynamic range (loud and soft musical sections) and a larger range could likely generate a stronger result. Put simply, if there was a larger inherent dynamic range in the stimuli before processing, then the perceived difference between compression values may be easier to perceive.

Finally, the playback level of the stimuli (76dB) was considered to be quite loud by the subjects. This level and also the directness of the near field monitoring in the listening sessions may not be representative of the average listening experience in the home. In general, it is unknown how both the level of playback and the addition of room reflections influences the perception of compression. It may be that reverberation has a significant masking effect on the subtle characteristics of compression, once stimuli exhibiting different amounts of compression have been matched to a given perceived loudness. Accordingly, further research is recommended that would address questions regarding what constitutes the perceptual cues allowing for the detection of variation in dynamic range compression under typical listening conditions.

6. APPENDICES

6.1. Appendix A – 'Multipressor' parameters.

Sti	Thresh	B1 gain	B2 gain	B3 gain	B4 gain	Out
1	N/A					
2	-17dB	0	0	0	0	0.4dB
3	-18dB	0	0	-0.5dB	-0.5dB	0.8dB
4	-19dB	0	0	-0.5dB	-1dB	1.2dB
5	-20dB	0	0	-1dB	-1.5dB	2dB
6	-21dB	0	0	-1dB	-2dB	2.4dB
7	-22dB	0	0	-1dB	-2dB	2.8dB
	Attack	65ms	30ms	47ms	26ms	
	Release	55ms	26ms	32ms	32ms	
Crossover points: 110Hz, 580Hz and 3100kHz						
Auto-gain (off) Look ahead 13.200ms Ratio (all bands) 3:1						

6.2. Appendix B – 'Adaptive Limiter' parameters

Stimuli	Gain	Input Scale	Out Ceiling
1	N/A		
2	3	-1.4dB	-0.03dB
3	5	-1.4dB	-0.03dB
4	7	-1.4dB	-0.03dB
5	8	-1.4dB	-0.03dB
6	9	-1.4dB	-0.03dB
7	10	-1.4dB	-0.03dB
Mode: OptFit Look ahead 50ms Remove DC (on)			

6.3. Appendix C – PSE adjustments on un-compressed stimuli

Genre	Level increase	Gain value
Dance	0dB	1.000
Pop	1dB	1.1220
Rock	1dB	1.1220
Acoustic	2dB	1.2589
Classical	2dB	1.2589

6.4. Appendix D – Recorded data

Option	Pop	Dance	Rock	Acoustic	Classical
1	5	1	4	4	11
2	3	5	4	6	4
3	9	6	6	4	1
4	3	4	3	4	4
5	6	4	6	4	2
6	1	6	5	4	2
7	2	3	1	3	5

7. ACKNOWLEDGEMENTS

This study was co-supervised by Dr. Ian Dash (many thanks), in partial fulfillment of the requirements for the degree of Master of Design Science (Audio and Acoustics) at the University of Sydney, Sydney, Australia.

8. REFERENCES

[1] Thiele, N. "Some Thoughts on the Dynamics of Reproduced Sound." *Journal of the Audio Engineering Society*, vol 53, issue 1/2, January/February, 2005.

[2] Vickers, E. "The Loudness War- Background, Speculation and Recommendations." *Proc. of the 129th Convention of the Audio Engineering Society*, San Francisco, CA, USA, November, 2010.

[3] Weymouth, D. "The Loudness War: A Game and Market Theory Analysis." Essay, GRIN publishing, November 30, 2012.

[4] Fletcher, H. and Munson, W. A. "Loudness, Its Definition, Measurement and Calculation." *Journal of the Acoustical Society of America*, vol 5, October 1933.

[5] Levitin, D. "This is Your Brain on Music: Understanding a Human Obsession." Atlantic Books. ISBN: 978 1 84354 716 7, 2006.

[6] Viney, D. "The Obsession with Compression." Master of Music Technology Thesis, London College of Music, Thames Valley University, December, 2008.

[7] Giannoulis, D., Massberg, M. and Reiss, J. D. "Digital Dynamic Range Compressor Design: a Tutorial and Analysis." *Journal of Audio Engineering Society*, vol 60, issue 6, June, 2012.

[8] von Ruschkowski, A. "Loudness War." *Proc. of the VDT - Seminar "An Eye On Hearing"*. Munich, Germany, October, 2009.

[9] Rumsey, F. "Mastering in an Ever Expanding Universe." *Journal of Audio Engineering Society*, vol 58, issue 1/2, January/February, 2010.

[10] Nielson, S. H. and Lund, T. "0 dBFS + Levels in Digital Mastering." *Proc. of the 109th Convention of the Audio Engineering Society*, Los Angeles, California, USA, September, 2000.

[11] Nielsen, S. H. and Lund, T. "Overload in Signal Conversion." *Proc. of the 23rd International Conference of the Audio Engineering Society*, Copenhagen, Denmark, May, 2003.

[12] Lund, T. "Distortion to the People." Essay, Denmark, 2004.

[13] Taylor, R. W. "Turn It Up, Play It Loud – Hyper-compression in Music Production: Listener Preferences on Dynamic Range Reduction". Masters Dissertation, University of Sydney. June, 2013.

[14] Bull, M. "No Dead Air! The Ipod and the Culture of Mobile Listening." *Journal of Leisure Studies*, vol 24, issue 4, August, 2006.

[15] Beer, D. "The Iconic Interface and the Veneer of Simplicity: Mp3 Players and the Reconfiguration of Music Collecting and Reproduction Practices in the Digital Age." *Journal of Information, Communication & Society*, vol 11, issue 1, June, 2008.

[16] ITU (International Telecommunication Union). "ITU-R BS.1770-3: Algorithms to Measure Audio Programme Loudness and True-Peak Audio Level." 2012.

[17] EBU (European Broadcast Union). "EBU Tech 3341 - Loudness Metering: 'EBU Mode' Metering to Supplement Loudness Normalisation in Accordance with EBU R-128." Geneva, Switzerland, August, 2011.

[18] Advanced Television Systems Committee (ATSC) Recommended Practice: Techniques for Establishing and Maintaining Audio Loudness for Digital Television (A/85:2013).

[19] Deruty, E. "*'Dynamic Range' and the Loudness War*." Sound On Sound, SOS Publications Group, Cambridge, UK. September edition, 2011. http://www.soundonsound.com/sos/sep11/articles/loudness.html