THE OBSESSION WITH COMPRESSION

A RESEARCH PROJECT DISSERTATION

BY

DAVE VINEY

POST-GRADUATE STUDENT OF AUDIO TECHNOLOGY

LONDON COLLEGE OF MUSIC

FACULTY OF ARTS

THAMES VALLEY UNIVERSITY
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1. Dissertation structure and assignment brief

This dissertation is the result of the author’s final project for a taught MA course in Audio Technology at the London College of Music (TVU) – the project was undertaken on a part-time basis between June & November 2008 based on a proposal submitted in April 2008 – deviations from that proposal are addressed in section 4.0 (Development) – this project represents an investment of considerably in excess of the 600 hours stipulated largely due to the need to create an extensive database in order to perform the required analysis.

This dissertation is structured in line with guidance provided by the course leader for this project but it has been adjusted in line with the nature of this project (research cf practical) – it contains extensive charts & tables in order to comply with the imposed word count limit.

Regarding data ownership and commercial value, TVU guidelines were consulted – no proprietary data has been used – primary research data has been obtained by the author from measurement equipment (loudness meter) and a volunteer assessment panel (with respect for personal confidentiality) - secondary research data was obtained from published sources (Music Week) – copyright in the primary data and the results of its consolidation & analysis rests with the researcher together with any associated commercial value.

The composite CD was compiled from original CDs purchased by the researcher and duplicates were provided to the assessment panel for non-commercial research purposes only – the copyright remains with the current owners.
2. Introduction & Background

The researcher is a mature post-graduate with a first career in the IT industry – he has been involved in music since childhood, initially as a performer (choral & instrumental) and subsequently as a composer & producer/engineer – he has composed, performed, produced & engineered a variety of rock/pop songs and currently sings in a cover band which gigs in pubs & clubs in aid of charity.

During his MA course, the author has been involved in a variety of work experience in the music business and has fully engaged with industry organisations (MPG, APRS, AES etc) – after submission of this dissertation, he will be considering the options of working within the music business or conducting further research.

The original inspiration for this project came from the ‘Audio Production Industry’ module of the course taught by the researcher’s supervisor and, as per the proposal, was ‘An investigation into correlations between certain musical & technical aspects of contemporary ‘popular’ music and its commercial success in the UK’.

The researcher attended an MPG event on 11/3/2008 to discuss the ‘Loudness Wars’(MPG News 2008) where producers & engineers complained bitterly at being coerced by labels & artists to apply a detrimental level of compression during final mastering in the belief (or hope?) that its sounding louder enhances its commercial success – the researcher established that no research was known to the MPG that had been conducted into this correlation and that its members would support such an initiative – this was endorsed by the APRS at one of their events on 19/3/2008 where they addressed the same subject via a complementary debate (‘The Dynamics Dilemma’) (APRS 2008) – these events are also referenced in Collins’ (2008) article in Prosound News in which the researcher is quoted.

The researcher agreed a plan with Tony Platt of the MPG who provided a listening panel of producers & engineers to assess the compression applied to 30 recent CD singles randomly selected from the UK charts – an initial proposal to ascertain this from the corresponding producers or mastering engineers was rejected as impracticable – it was also decided to obtain a loudness meter to make objective measurements for comparison with the panel assessments.

Consequently, the focus of the project shifted towards investigating the correlation between commercial success and compression rather than musical attributes – this was reviewed & agreed with the researcher’s supervisor and became the basis of the project.
3. Background Research

Discussion of this subject with friends & family revealed a common confusion between compression of dynamic range as addressed by this project with size/space compression as exemplified by MP3 file formats – the author suspects that this confusion may extend to many less technical members of the music community including the media (press etc) causing a confusion between loss of quality due to dynamic processing and that due to CODECs – perhaps the industry should use more precise terminology to distinguish between dynamic & data compression?

The history of dynamic compression is long & contentious from the early days of tape through outboard analogue devices to the latest digital plug-ins including its use for unnatural effects (gating, pumping & multing etc) especially on vocals, guitars/bass & drums as well as its use during final mixing or mastering to increase loudness – a good overview appears in Zak 2001 pp122-5.

One piece of loosely related research was conducted by a previous student of this course but this investigated the musical attributes of chart number ones over a period of 40 years rather than the technical attributes of a range of chart singles over a short period of time – one conclusion was that the popularity or introduction of new genre was driven by social/political/economic circumstances often as a revolt against authority (parents/school/government etc) – recorded music is often a teenager’s first asset purchase with their own (earned or pocket) money and so has strong emotional attachment.

Research of academic databases and music industry information sources (MPG, APRS, BPI, AIM, IFPI etc) did not reveal any previous or current research into this specific area of correlation between compression/loudness and commercial success suggesting that this research may be breaking new ground.

Enquiries to other universities (Edinburgh, Surrey, Exeter, Glamorgan, Westminster, Goldsmiths college) did not change this impression but did identify some related relevant research including that into the effect of memory (due to previous hearing) on musical listening/appreciation.

Michael Bull’s research into mobile music listening (Ward 2004), (Kahney 2004) & (Millard 2004) gives some insight into why & how people use mobile music devices and what they listen to but not what drives their listening choice.

The most significant background and reference points for this research are discussion fora hosted by industry organisations such as the MPG, APRS etc as discussed above – this was reinforced by a seminar hosted by the MPG at the LIMS exhibition at Excel in London on 14/6/2008 attended by the researcher whose project was cited by the MPG.

Another reference point was a TVU ‘mastering’ master class held on 7/5/2008 by Duncan Cowell of Sound Mastering who was insistent that a unique mastering process is appropriate whatever the delivery channel or listener environment/equipment rather than the multiple mastering option implied by the Metallica situation discussed below or by using metadata to define the mastering parameters in order to allow downstream adjustments (see email in section 15 (Support Documentation) & (Lund 2006).

The only directly relevant reference that the researcher has uncovered is that made by Mick Glossop (2008) on his MPG blog where he acknowledges the success of many heavily compressed records from Joe Meek onwards.

Though not a reference as such, Wikipedia has an interesting & recently updated page on the ‘Loudness War’ which includes a useful summary of the history & status of dynamic compression – another interesting chronology is outlined in an anonymous article hosted by Mike Richter’s website (‘The Death of Dynamic Range’ 2008).
The topicality of this subject was reinforced by several recent developments – one was the introduction in July this year of legislation to prevent TV broadcasters from increasing the loudness during commercial breaks, ending one of the most irritating aspects of watching commercial TV channels (BBC News 2008).

Another was the reaction of Metallica fans to the ‘Death Magnetic’ (released by Warner) CD as reported in ‘You & Yours' on Radio 4 on 10/10/2008 that it earned complaints by fans via the Metallica website blog that it is too loud & distorted – SRT mastering engineer Ian Shepherd referred to the ‘loudness wars’ and explained that the CD differed from the sound track used for the ‘Guitar Heroes’ computer game that was released before the CD – he referred to a website that shows that the CD is digitally clipped resulting in distortion and significantly louder than other CDs including previous CDs by Metallica – he claimed that this extreme use of compression was not new having started with Phil Spectre’s ‘wall of sound’‘Motown’ recordings and exemplified by the Red Hot Chilli Peppers ‘Californication’ – Shepherd’s blog (2008) contains more detail and a ‘YouTube’ video ‘The Loudness War Explained’ – other videos are referenced on the MPG website showing comparisons of the 2 versions of ‘Death Magnetic’ (Calavera 2008) and other evidence of over compression including the chronology of the obsession and quotes from music industry gurus (Ajuk1 2008), (Geekvideo 2007), (Wichtelchen2006 2008) & (Mayfield 2006) – other commentaries are included in the bibliography.

On a reprise of this subject during ‘The World Today’ on the BBC World Service on 26/10/2008, another mastering engineer, Simon Hayworth of Super Audio Mastering, suggested that appreciation of loudness was age dependent – this is outside of the scope of this project but constitutes an interesting area of further research.

However this issue is not new as witnessed by the comments of a couple of experienced producers 15 years ago who even refer to mastering for radio in anticipation of broadcast compression (Ford 1993, pp.136-8).

On the general subject of loudness in music, there is plenty of information on the internet and even a dedicated organisation ‘Turn Me Up’ (2008) which has links to many sources including several referenced in this document or included in the bibliography.
4. Project Development

Apart from the focus on technical attributes, especially compression, rather than musical attributes, the project developed largely in line with the original proposal – it was established that sources of musical attributes (key, bpm, time signature etc) were not readily available requiring primary research to establish this data – the scale of the data processing involved necessitated some reduction in scope from the original proposal – these are outlined below.

Minimal dependence was made on TVU resources – regular (monthly) reviews were held (or reports submitted) with the researcher’s supervisor and feedback incorporated into the project plan.

The original plan for the assessment panel was to include labels, pluggers (PR), distributors, retailers & consumers in addition to producers & engineers from the UK & USA - considerable effort was made via the BPI, AIM & ERA as well as individual distributors & retailers to secure listening panel members from other parts of the music industry but without success – the researcher concluded that, perhaps exaggerated by the current turmoil, the industry does not seem to attach much value to external research and is perhaps suspicious of anyone doing so.

The UK P&Es (26) were recruited from the MPG & APRS and the USA P&Es (25) were nominated by the RA via an MPG introduction – 36 of the 51 volunteers participated.

It was decided to use singles rather than albums since it would be impossible to associate album chart sales data with radio/TV airplay data nor the technical attributes of their constituent tracks, especially compilations where the mastering could vary between tracks.

After investigation of the charts published in Music Week and Billboard, it was decided to use Music Week charts as the source of commercial data as they separate sales from radio & TV airplay whereas Billboard publish composite charts combining sales & airplay – Music Week publishes the top 75 singles based on UK sales plus the top 50 based on radio airplay and top 40 for TV airplay – see section 15 (Support Documentation) for further information.

It was originally hoped to select the sample music from the USA (or WW) charts to cover a broader range of genre but, in addition to the constraints of published charts, it was established from a sample Billboard chart that many of the singles were not available (even in USA) on CD (i.e. download only) – it had already been agreed with the MPG that the selected music should be available on CD to allow an assessment of the ‘best’ commercial quality available – this necessitated their selection from the UK (Music Week) charts – it should be noted that the MW singles charts include (legitimate) downloads as well as actual CDs.

To obtain a ‘random’ sample, selections were made from positions 1, 25, 50 & 75 of the Music Week singles charts for the weeks from 12/4 to 12/7/2008 with pre-release, vinyl & download-only excluded – recent singles were chosen both to minimise the effect of influences due to other factors changing over time - this selection was then gated by their availability from HMV online (both HMV & Zavvi were solicited for assistance in providing the CDs as part of their invitation to participate on the assessment panel but both declined) – this resulted in 32 CDs received of which the first 30 in alphabetic order of track name were selected for the assessment – this was considered the maximum that the assessment panel could be expected to listen to.

The questionnaire was drafted & reviewed with the MPG before being distributed to the panel with the composite CD.

Some delay was incurred due to the sudden unavailability of the mastering engineer who had kindly volunteered to compile the composite CD - a replacement was found via the MPG and the planned schedule adjusted within the built-in contingency.
The initial plan regarding commercial data (sales & airplay) was to obtain it from the UK Chart Company & PPL but as, despite repeated requests, their cooperation was not forthcoming, the researcher was obliged to create a database from the individual Music Week journals – initially, the researcher obtained the data from the Music Week online database but, as its subscriber access is restricted to only the previous 3 months and some of the selected tracks were in the charts for many weeks before the sampled period, it was necessary to access the individual online journals and, where missing, actual library hard copies – initially, it was planned to include relevant data from 3 months both before & after the sample period but, in order to track the chart history of the selected tracks, this had to be extended from May 2007 to November 2008 (19 months!).
5. Structure and content

5.1 Data Structure & Database

The overall data structure employed in this project is shown below

![DATA STRUCTURE Diagram]

Quantitative loudness was measured using a professional loudness meter.

Qualitative assessment was made via the questionnaire and composite CD.

Commercial data was extracted from sales & airplay data from Music Week.

The database was developed to accommodate all of the above data in a structured way such that it could be readily analysed using Excel functions & charts – it consists of 2 workbooks, one with a worksheet for each of the 30 tracks containing the detailed commercial sales & radio/TV airplay data (see section 7 Data Analysis for an example) and the other with a worksheet for each question of the questionnaire containing the detailed responses of the panel plus the summary of the loudness meter readings (details in separate workbooks for each full track & excerpt), commercial data and panel assessments (see section 6 Technical Considerations for an excerpt).

The commercial data was initially transcribed from the Music Week Data online subscription service but this was found to be incomplete and often inconsistent – efforts to resolve this with Music Week met with no response – additionally, as the service only gave access to the previous 3 months data and that required extended back to before the sample period, it was necessary to access it from the individual journals as discussed above – the transcription was cross-checked from the ‘previous week’ data but, where there were inconsistencies, the current week data was used – chart re-entries were ignored.
5.2 The Assessment Questionnaire

The questionnaire had to be a compromise between producing meaningful data which could be correlated with other sources (commercial sales/airplay and quantitative loudness data) and being simple & not too time consuming to complete – it was decided to restrict it to basic demographic & environment data about the listener and 9 basic assessments of the tracks – this required 281 data items per assessor which, together with the composite CD, was intended to be completed within 60 minutes - see section 15 (Support Documents) for the questionnaire with panel briefing and completion instructions.

The questionnaire was provided to assessors in both soft (PDF & DOC) & hard copy format to facilitate completion and so responses were received in various formats (PDF, DOC, XLS & hardcopy including handwritten) – this necessitated considerable transcription and clean up to ensure a valid analysis – upper/lower case consistency was addressed and checksums were employed in the database to identify inconsistencies or transcription errors and invalid/unclear responses validated with the panel – in the event of multiple answers, the first was taken except for ‘producer & engineer’ which was coded as ‘producer/engineer’ and an answer of ‘home studio' was coded as ‘home’.
6. Technical considerations

6.1 Composite CD
The composite CD was produced by a professional mastering engineer on behalf of the researcher – it was compiled from the original CDs purchased by the researcher using the first 90 seconds of the first track (radio edit) of each CD to produce a red book standard audio CD containing 30 tracks of 90 seconds – the transfers were performed digitally via ProTools without any processing or level adjustment to ‘preserve’ the quality & loudness/compression of the original CD.

The composite master CD was professionally duplicated by Duplidisk on an R-Quest TCP-7550 unit and labeled by the researcher including copyright warnings as advised by a music lawyer whom the researcher consulted - see section 15. Support Documentation for an extract from the relevant copyright law.

6.2 Loudness Measurements
These were made using a loaned DK Technologies MSD600M++ audio level meter (DK-Technologies 2007) using a Traxdata Traxaudio 900 CD player connected directly to the meter’s digital (AES) stereo input using the LEQ summing method as per BS1770 (RLB LU application) and with RLB 0 set at -20dBFS (Brixen 2007).

The meter was connected via its RS232 (serial) interface via a USB adaptor to the researcher’s PC using the DK-LevelRead application to capture the readings at 1 second intervals and to import them directly into Excel workbooks (see below for a sample).

The excerpt readings were made from the master composite CD but a duplicate (as distributed to the panel) was checked to verify that they were the same – readings were also taken from the full tracks on the original CDs – average & maximum readings for both excerpts & full tracks were derived and entered into the database for analysis.
6.3 Workbooks & Charts

These were created using Microsoft Office Excel 2007 using standard functionality (no add-ins) – correlations were assessed using the provided =CORREL function (see extract from Excel ‘help’ in section 15 Support Documentation and (Easton & McColl 2008) for details) – line charts were used to plot commercial source data, bar charts to display consolidated assessment data and scatter charts to show correlations.
7. Data Analysis

Considerable effort has been made to present the source data in graphical form to facilitate the readers understanding due to the quantity involved – the raw data resides in the database workbooks which are supplied on the accompanying CD – excerpts of the workbooks are included in this document only as examples of the database structure.

7.1 Commercial Success

Sales chart & radio/TV airplay data for each week from entry to exit was entered into the database as per the example shown below.

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<th>radio position</th>
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</table>

The following charts show the sales chart & radio/TV airplay positions week by week for each of the 30 tracks – many show a strong correlation between sales & radio/TV airplay (e.g. tracks 1, 3, 5, 7 11 & 25) with indications in some cases that airplay appears to drive rather than follow sales – others suggest that other influences are probably at work where sales continue long after airplay has ceased (e.g. tracks 22, 26 & 29) especially when there is a manifestation of the ‘dead cat bounce’ syndrome (see track 22).
Note that several tracks achieve high sales without any 'build up' or significant airplay exposure suggesting that other highly effective marketing channels are being used prior to release.

Notable deviations from the typical picture are tracks which appear to enjoy sales success without airplay exposure again suggesting other marketing influences (e.g. tracks 12, 21 & 24)
7.2 Panel Assessments

The questionnaire & composite CD was sent to 51 ‘volunteers’ of whom 36 responded - all respondents were male – sadly the only female volunteer did not respond!

Responses to the questionnaires were transcribed into the database and then converted to corresponding numeric values to facilitate analysis.

The following charts summarise the demographic data from the assessment questionnaires.

Ages were spread but with large spike in the 55-59 range.

All but 1 classified themselves as either producer or engineer (or producer/engineer).

The listening environment was split 60/40 between studio & home and professional & consumer CD players.

The vast majority listened via loudspeakers.

All but 1 was prepared to enter into discussions about compression with 2 indicating that they were not qualified to discuss it.

20 respondents were resident in UK, 14 in USA and 1 each in Finland & Turkey.
The charts show on the following pages show the responses by track for each question – they are grouped by question to facilitate comparisons between the 30 tracks.
7.2.1. Question 1 (Have you heard it before?)
The majority responded that they had not previously heard most of the tracks – only tracks 3, 13, 16, 24, 29 & 30 showed any significant recognition with only track 29 having majority recognition – interestingly, this was the track with the longest time in the sales charts (52 weeks!). This suggests that ‘prior hearing’ was not a significant factor in these assessments.
7.2.2 Question 2 (Were you involved in its recording, production, marketing, distribution or sale?)

Only 1 respondent indicated any involvement with just 1 track (track 22).
7.2.3. Question 3 (How would you classify its genre?)

For about half of the tracks, the classification was (almost) unanimous but for the rest, the classification was split between at least 2 genres with 3 or 4 showing a 3 way split – there were no tracks classified unanimously as country/bluegrass, latin or classic/jazz.
7.2.4. Question 4 (What makes it distinctive/special/different?)

This was one of the most interesting set of responses in that there was limited agreement between respondents as to what distinguished the selected tracks— the most consistent response was 'nothing' but other responses were relatively evenly distributed.
7.2.5. Question 5 (How would you rate the sound quality?)

Like the previous question, there was far from unanimous agreement amongst the listening panel – the extremes were track 25 (pleasant) & 12 (unpleasant).
7.2.6 Question 6 (How would you rate the overall sound quality versus other CDs?)

Again, limited unanimity but most tracks have majority responses in adjacent bands—the lowest rated track was 12 – there was no clear winner but the highest rated track on average was 25.
7.2.7. Question 7 (How does it sound compared to the other tracks on this CD?)

Like the previous question, limited unanimity but most tracks have majority responses in adjacent bands – however, the majority response was ‘same’ indicating some difficulty in assessing the relative loudness of the tracks - also, interestingly, the tendency was to assess tracks as louder rather than softer (by a factor of 2 to 1).
7.2.8 Question 8 (How would you assess its overall level of overall compression?)

Again, far from unanimity but most tracks have majority responses in adjacent bands and the majority response was ‘too much’ rather than ‘too little’– the best agreement was for track 18 (‘about right’).
7.2.9. Question 9 (How would you assess its overall level of overall processing (EQ etc)?)

Similar to question 8, the majority response was for ‘too much’ rather than ‘too little’ – the closest agreement was ‘about right’ (e.g. tracks 2, 3, 24, 25 & 26).
7.3 Actual Loudness

The charts on the following 2 pages show the actual loudness second by second for each of the 30 full tracks together with averages & maxima – large variations are evident in the loudness profiles of the 30 tracks – some show significant variations in loudness (e.g. tracks 7, 22 & 24) whereas others exhibit little change (e.g. tracks 2, 4 & 8).

Average loudness of excerpts varied from 8.3 to 15.1 with an average of 11.7 – maximum from 11.2 to 16.7 with an average of 14.4 – average/maximum percentages vary from 59% (track 23) to 94% (track 8) with an average of 81% indicating the range of dynamic variations – see chart below.

Average loudness of full tracks varied from 9.1 to 15.4 with an average of 12.2 – maximum from 11.8 to 16.8 with an average of 15.1 – average/maximum percentages vary from 67% (track 23) to 93% (track 8) with an average of 81% indicating a slightly smaller range of dynamic variations than the excerpts – see chart below.
Average = 12.9  maximum = 15.6  
Average = 13.4  maximum = 15.2  
Average = 12.0  maximum = 15.3

Average = 11.8  maximum = 14.8  
Average = 13.3  maximum = 15.4  
Average = 10.9  maximum = 13.2

Average = 10.4  maximum = 14.0  
Average = 15.4  maximum = 16.6  
Average = 12.7  maximum = 14.6

Average = 13.5  maximum = 15.7  
Average = 12.4  maximum = 14.2  
Average = 14.1  maximum = 16.8

Average = 11.6  maximum = 15.1  
Average = 13.2  maximum = 15.5  
Average = 12.7  maximum = 16.0
7.4 Correlations

In order to investigate correlations other than those directly under investigation, a matrix of correlation coefficients between commercial, assessment & loudness data was created as per the sample below (see section 15.0 Support Materials for full database on CD) – the coefficients are colour coded to highlight high (green), medium (yellow) & low (red) correlations – the following charts show the corresponding correlation coefficients as ‘cc=n.n’.

| correlations                | weeks in charts | top chart position | average chart position | top chart date | weeks on radio | top radio position | average radio position | top radio position date | weeks on radio | top radio play | average radio play | top radio play date | weeks on radio | top radio audience | average radio audience | top radio audience date | weeks on tv | top tv position | average tv position | top tv position date | weeks on tv | top tv play | average tv play | top tv play date |
|-----------------------------|-----------------|--------------------|------------------------|----------------|----------------|-------------------|-----------------------|------------------------|-----------------|----------------|--------------------|----------------------|-----------------|----------------------|----------------------|----------------------|----------------|----------------|----------------|-----------------|
| weeks in charts             |                 |                    |                        |                |                |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top chart position          | -0.7            |                    |                        |                |                |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average chart position      | -0.5            | 0.9                |                        |                |                |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top chart date              | -0.6            | 0.3                | 0.2                    |                |                |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| weeks on radio              | 0.7             | -0.7               | -0.7                   | -0.2           |                |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio position          | -0.5            | 0.6                | 0.6                    | 0.3            | -0.8           |                   |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average radio position      | -0.4            | 0.5                | 0.6                    | 0.4            | -0.7           | 0.9               |                       |                        |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio position date     | -0.6            | 0.3                | 0.1                    | 1.0            | -0.2           | 0.3               | 0.3                   |                       |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| weeks on radio              | 0.7             | -0.7               | -0.7                   | -0.2           | 1.0            | -0.8              | -0.7                  | -0.1                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio play              | 0.6             | -0.6               | -0.6                   | -0.3           | 0.9            | -0.8              | -0.7                  | -0.2                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average radio play          | 0.6             | -0.7               | -0.6                   | -0.3           | 0.9            | -0.8              | -0.7                  | -0.2                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio play date         | -0.5            | 0.2                | 0.0                    | 0.9            | 0.0            | 0.2               | 0.2                   | 1.0                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| weeks on radio              | 0.7             | -0.7               | -0.7                   | -0.2           | 1.0            | -0.8              | -0.7                  | -0.1                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio audience          | 0.6             | -0.7               | -0.5                   | -0.3           | 0.9            | -0.8              | -0.8                  | -0.3                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average radio audience      | 0.5             | -0.6               | -0.5                   | -0.4           | 0.8            | -0.9              | -0.9                  | -0.3                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top radio audience date     | -0.6            | 0.3                | 0.1                    | 1.0            | -0.2           | 0.3               | 0.3                   | 1.0                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| weeks on tv                 | 0.7             | -0.7               | -0.7                   | -0.3           | 0.8            | -0.6              | -0.4                  | -0.2                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top tv position             | -0.7            | 0.8                | 0.8                    | 0.2            | -0.8           | 0.7               | 0.5                   | 0.2                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average tv position         | -0.7            | 0.8                | 0.8                    | 0.2            | -0.8           | 0.8               | 0.6                   | 0.2                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top tv position date        | -0.5            | 0.1                | -0.1                   | 1.0            | 0.0            | 0.2               | 0.3                   | 1.0                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| weeks on tv                 | 0.8             | -0.7               | -0.7                   | -0.3           | 0.9            | -0.6              | -0.5                  | -0.2                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top tv play                 | 0.7             | -0.8               | -0.8                   | -0.2           | 0.8            | -0.6              | -0.5                  | -0.1                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| average tv play             | 0.7             | -0.7               | -0.7                   | -0.2           | 0.8            | -0.6              | -0.5                  | -0.1                  |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
| top tv play date            | -0.4            | 0.1                | -0.1                   | 1.0            | 0.0            | 0.2               | 0.2                   | 1.0                   |                 |                |                   |                      |                 |                      |                       |                     |                |                |                   |                  |
7.4.1 Commercial Success
The following charts show the correlations between top positions, top dates and weeks in charts for sales, radio & TV airplay for the 30 tracks – perhaps not surprisingly, there are many high correlations in this area but further research (outside of the scope of this project) is required to determine which are leading & lagging factors.
7.4.2 Panel Assessments
The following charts show those questions in the panel assessments that exhibit the most significant correlations for the 30 tracks – these show high correlations between questions 5, 6, 8 & 9 indicating that ‘pleasantness’ & ‘quality’ are associated with low levels of ‘compression’ & ‘processing’.

Key to axes
q5) How would you rate the sound quality? 1 = pleasant to listen to, 2 = unpleasant to listen to
q6) How would you rate the overall sound quality versus other CDs? 1 = well below average, 2 = below average, 3 = average, 4 = above average, 5 = well above average
q8) How would you assess its overall level of overall compression? 1 = far too much, 2 = too much, 3 = about right, 4 = too little, 5 = far too little, 6 = not qualified to assess
q9) How would you assess its overall level of overall processing (EQ etc)? 1 = far too much, 2 = too much, 3 = about right, 4 = too little, 5 = far too little, not qualified to assess
7.4.3 Actual Loudness

The following charts show significant correlations between the loudness of the excerpts versus the full tracks - this should dispel any concerns regarding possible distortions of the analysis due to the assessments being based on listening to the excerpts whereas the commercial data is based on the full tracks.

A comparison of both average & maximum loudness between excerpts & full tracks is shown in the following charts.
7.4.4 Commercial Success versus Panel Assessments

The following charts show correlations between sales & radio/TV airplay data versus the panel assessments for the 30 tracks – these show that there is little correlation between sales chart positions or weeks in charts with questions 5 (‘pleasantness’), 6 (‘quality’), 7 (‘loudness’), 8 (‘compression’) or 9 (‘processing’) – the strongest (medium) correlation is between sales chart position & ‘pleasantness’ or (little) ‘processing’ – interestingly, there is a high correlation between top radio position and question 9 (little) ‘processing’.

![Charts showing correlations between sales & panel assessments](image-url)
Key to axes

q5) How would you rate the sound quality? 1 = pleasant to listen to, 2 = unpleasant to listen to

q6) How would you rate the overall sound quality versus other CDs? 1 = well below average, 2 = below average, 3 = average, 4 = above average, 5 = well above average

q7) How does it sound compared to the other tracks on this CD? 1 = much louder, 2 = slightly louder, 3 = same, 4 = slightly quieter, 5 = much quieter

q8) How would you assess its overall level of overall compression? 1 = far too much, 2 = too much, 3 = about right, 4 = too little, 5 = far too little, 6 = not qualified to assess

q9) How would you assess its overall level of overall processing (EQ etc)? 1 = far too much, 2 = too much, 3 = about right, 4 = too little, 5 = far too little, not qualified to assess
7.4.5 Commercial Success versus Actual Loudness
The following charts show the correlations between sales chart data versus the actual loudness of the 30 full tracks – this shows that there is no significant correlation between sales chart position or weeks in chart and the actual loudness of the full tracks – since sales chart & radio/TV airplay are correlated (as discussed above), the same lack of correlation applies to radio & TV airplay..
7.4.6 Actual Loudness versus Panel Assessments

The following charts show the correlations between the actual loudness measurements (of the excerpts) versus the panel assessments of ‘loudness’ & ‘compression’ for the 30 tracks – these show medium correlations between actual loudness and assessed ‘loudness’ or ‘compression’ – not surprisingly, the assessments are correlated more closely with average rather than maximum loudness.

Key to axes

q7) How does it sound compared to the other tracks on this CD? 1 = much louder, 2 = slightly louder, 3 = same, 4 = slightly quieter, 5 = much quieter

q8) How would you assess its overall level of overall compression? 1 = far too much, 2 = too much, 3 = about right, 4 = too little, 5 = far too little, 6 = not qualified to assess
8. Critical appraisal

8.1 Project Structure & Scope
Overall, this was a very successful project – although it changed slightly from its initial scope, the original structure proved sound and the plan was sufficiently flexible to accommodate the changes - its focus on a topical subject appealed to the author who is torn between working in the business and performing further research – although the researcher is only a part-time student, this project resulted in greatly in excess of the stipulated 600 hours effort largely due to the data gathering & analysis required – this & other factors affecting the project are described below.

The researcher is confident that, within the constraints of the project, it has produced some valuable data & analysis on the subject and has established a sound basis for further research into this area of commercial music – one possible weakness is that the constraints of time and the length of this dissertation have limited the amount of analysis that could be performed & presented – the data collection could have been further reduced but the researcher felt that this would have compromised the analysis.

Although the results are not entirely conclusive, they do indicate some interesting correlations (or lack of them) in a highly commercial area that abounds with opinion but scant facts (including previous or concurrent research) – the author hopes that this initiative might inspire others both inside & outside of the business to both perform & support similar future research.

One generic criticism of research into the ‘arts’, especially from the music industry, is that it does not lend itself to ‘scientific’ analysis with the implication that commercial success is due to factors that cannot or are too complex to be measured – the author, having a scientific background, tends to agree with Zanette (2008) who, in his Nature article ‘Playing by numbers’, intimates a parallel with the world creation versus evolution debate – over time, mystery is replaced by understanding – commercial success of popular music may be based on a complex combination of factors (including marketing, environmental, psychoacoustic etc) but they are there to be discovered!

8.2 Music selection
The selected music represents a relatively narrow range of genre but the reasons for their choice has been explained in section 4.0 (Development) – it may be that a wider choice, e.g. CDs that did not get into the charts, would have shown a wider (or different) range of loudness/compression but this would have posed the challenges of their availability and lack of commercial data.

Many CD ‘singles’ have multiple tracks on them, often with multiple versions of the title track – the first track, usually labeled radio edit or album track (as opposed to a remix) was assumed to be that played on radio & TV and thus represented by the radio & TV airplay charts – this may not have always been the case.

The 90 second excerpts of the CD singles were used to limit the time commitment of the listening panel but there is evidence that subject evaluations of music can be heavily influenced by ‘editing’ (Sloboda, 2008) – it may be therefore that different assessments would have resulted from listening to the full tracks.
8.3 Commercial Data

The availability of commercial data is crucial to this research – although it is available as published in journals such as Music Week, it is a slow, tedious and error prone process to transcribe it into a form (e.g. Workbook) that can be readily analysed – other online sources such as Music Week Data, Billboard Biz & UK Chart Company offer limited access to the underlying databases – ideally, the researcher would have had open access to the published data in these databases but requests for this were not successful nor, in some cases, even responded to – this was both a voyage of discovery & disappointment for the researcher – it is hoped that publication of this report within the industry might play a part in persuading them to be more cooperative and that much is to be gained by supporting research into commercial success – it should also be of interest to radio & TV broadcasters to facilitate the availability of this and other data (e.g. broadcast compression) to better understand their relationship with commercial success.

There is ample data for related research - for instance, it is often suggested that compression is employed to make tracks sound louder (presumably than those which don’t) when played in clubs – in addition to their sales success, it might be revealing to investigate the loudness of those tracks that are most popular via the published ‘club’ charts.

Another potential area of analysis would be to investigate any correlation between loudness measurements or assessments and label (majors & indies) but this would probably need a larger sample to be statistically significant.

Assuming that radio & TV airplay has an influence on single sales, the question arises as to what version is played (single, album, remix) and whether the ‘loudness’ is heard in a typical listening environment – this situation is further muddied by the increasing tendency to buy formats other than CD (download, ringtone etc) which also contribute to the sales data – great care must be taken in interpreting the analysis – a correlation shows that 2 sets of data are related but not which influences the other – this requires more sophisticated time related analysis.

8.4 Assessment Panel

The panel of producer & engineers represents a technically & musically knowledgeable segment of the music business with a clear interest in the outcome of this research – although there is no suggestion that the responses are biased in any way, it may be that significantly different results would be obtained from assessments by others, especially (relatively) unknowledgeable consumers – however, without a readily available & cooperative supply of volunteers, the use of a more extensive panel proved to be beyond the scope of this project.

The BPI, AIM, ERA and individual retailers & distributors (including HMV, Zavvi & PIAS) were invited to participate or to nominate their members but, where responses were received, they declined the opportunity indicating perhaps that, in these unhappy (commercial) times, there is at best an apathy if not a suspicion of research into this area.

8.5 Questionnaire

The design criteria are described above but, with hindsight, it could have been improved by making it clear that only single answers were requested and perhaps asking about experience (as opposed to age) – a few listeners expressed difficulty with question 7 (relative loudness) which perhaps could have been better expressed.

Given the amount of data transcription involved from responses supplied in DOC & PDF documents, it would have saved the researcher a lot of time (including verification of transcription) if the responses had been solicited & supplied in XLS format.
8.6 Loudness Measurements
There was considerable delay in obtaining the loan of and technical support for the loudness meter but, once set up, was very straightforward to use – however, it was noted that long fades (in or out) could significantly affect the calculation of average loudness, especially the 90 second excerpts – it was also noted that the actual lengths of the full tracks often varies significantly from that indicated on either the CD label or sleeve and that silence was sometimes included at the start or end of the track – this was excluded from the readings.

It can be seen from the analysis that the average & maximum loudness can be significantly different – whereas the average/maximum ratio gives some indication of the variability in the actual loudness, it does raise the question as to which level the perceived loudness in question 7 of the questionnaire refers.

8.7 Data Analysis
The analysis is limited by both constraints of time and dissertation length – the database contains over 21,000 independent source values plus derived data – consequently, the focus in this document is on summaries of the source data and correlations of particular interest & significance – various statistics including minima/averages/maxima & spreads of data ranges are included in the database, primarily to check data integrity, but these have not been separately analysed or charted.

Some data (e.g. radio/TV plays & audience) have not been fully analysed or presented - considerable further analysis of the database is possible including correlations between the assessments for a given track or question to explore the consistency of responses between assessors across tracks & questions – similarly, further analysis could be performed of the time spans between release date and chart entry/peak/exit.

Further directly related areas of research could include investigation into the detailed loudness profiles of selected tracks, demographic differences in assessments of quality and the interactions of sales & radio/TV airplay – the latter could include a time dependent analysis of the dynamics to establish leading & lagging factors.

8.8 Third Party Feedback
The researcher solicited feedback from several academic institutions with a reputation for related research as well as industry organisations (see next section) – though some very helpful feedback was received, the researcher was particularly disappointed with the lack of support from academia – responses from the industry were also sparse, as were requests for assistance discussed earlier, but there were some mitigating circumstances (discussed below).
9. Third party feedback

During the data analysis, several of the listening panel were consulted to clarify unclear or conflicting responses.

Approaches were made to several academic institutions (CCI at Glamorgan, CHARM at Royal Holloway, Edinburgh, Exeter, Goldsmiths, Surrey and Westminster) and industry organisations (AES, AIM, APRS, BPI, ERA, IFPI, MMF, MPG, MU, UK Music) to review the draft – responses were received from the following whose comments resulted in revisions to the draft.

Kim Bayley, Director General, Entertainment Retailers Association
Mike Collins, (Recording Engineer / Producer / Studio Musician / Composer)
Dr. Chris Kennett, University of Westminster
Tony Platt, Director, Music Producers Guild
Derek Varnals, Technical Advisor, BPI

This feedback is included on the data CD - see Section 15 (Support Documentation).

It should be noted that, apart from the general situation described elsewhere in this document, at the time requests were made to review this dissertation, distributors Entertainment UK and Pinnacle announced financial difficulties causing further anguish within the recording industry.

The researcher also had a short conversation with Robin Millar (Arts Media) at the PPL APM at Abbey Road Studios on Monday 17/11/08 – he was very interested in the preliminary analysis and suggested follow up research (see section 10.3).
10. Conclusions

10.1 Environment

The music industry is in turmoil – apart from the ‘loudness wars’, the record companies are suffering from the consumer power delivered by the internet with consequent impacts on the rest of the music business – businesses are desperately seeking new models which can accommodate this new environment while artists exploit the opportunities that it brings.

The researcher would argue from his extensive business & marketing experience that this is precisely the time when businesses need guidance based on knowledge derived from rigorous research – however, the music business has thrived for decades without the need to have an in depth understanding of the real success factors – it is all well & good knowing what works in a stable environment but an understanding of the underlying drivers is needed to be able to adapt to a changing environment - now, like the general economy (and perhaps for not altogether different reasons), the boom has turned to bust and there is an urgent need for new paradigms.

The researchers experience of soliciting support from the industry for this project (with notable exceptions) and from seeking work experience during the 2 years of his part-time course is that the industry, apart from being somewhat suspicious of ‘outsiders’, has not yet fully embraced the value of rigorous research, especially that performed in academia – there is some evidence that the larger music companies are turning to business consultancies with specialised knowledge for insight & guidance into their predicaments but much of the established industry appears to be determined to resolve it from within their own resources.

This may be largely a matter of industry maturity, like many before it - the researcher, with an interest in crossing this divide can only hope that this situation improves and that this research might play a part, however small, towards that end.

10.2 Results

The key finding, in the context of this project, has to be that, based on the sample of 30 CD single tracks from recent months, there is no evidence of any significant correlation between loudness (& implied compression) and commercial success – this is based on both actual loudness measurements and assessments of professional producers & engineers between which there is significant correlation.

Whether this can be extrapolated to albums is not obvious but this result should provide a sounder basis for challenging the obsession with compression and encouraging further research into the actual factors determining commercial success.

On the assumption that listening to a charting single could have some influence on sales of the associated album that features it, this result could be enhanced by investigating the correlation between the singles loudness & assessment data with the commercial success of the associated album.

A secondary but supporting finding is some evidence from correlations between panel assessments and commercial data that recordings with little ‘processing’ & ‘compression’ sound ‘more pleasant’ & ‘above average quality’ and are more commercially successful – this is of course based only on the assessments of professional/technical listeners and may not apply to untrained consumers, especially those who buy music that reaches the single charts.
Assessments are highly subjective, even amongst professional producer & engineers, and may be correlated with demographic or environmental factors.

Sales success is closely interlinked with radio & TV airplay but other (unidentified) marketing factors are often involved – this is a contentious area and this research shows clearly that there is a complex relationship between the sales & airplay success with no single pattern – while there is evidence that airplay responds to sales, especially for those singles that are promoted to the top of the charts immediately after release by other (marketing) influences, there are also strong indications that sales success often follows significant airplay exposure though there could be (and probably are) other factors at work.

The results show that actual loudness varies considerably by track and this suggest that loudness profiles (patterns of dynamic change) may be more important than overall (average or maximum) loudness in determining its perceived level – the researcher suspects that, though not specifically researched for this project, there are some studies in this area but it would be a relatively simple experiment to produce some sound tracks with different loudness profiles and correlate them with the assessments of a listening panel – however, these ‘synthetic’ tracks may not (depending on the sound content used) be representative of real tracks – another approach might be to derive some measurements of the variability of the loudness f the real tracks.

10.3 Further Research

As discussed above, the constraints on this project have limited some aspects of the research as well as analysis of the data already gathered – further time (& dissertation space) and closer cooperation with industry bodies could have allowed further research into these areas.

As per the original proposal, extending the research to assessment panels of A&R, PR, distributors, retailers & consumers would cast some light on the different perceptions of the various components of the music industry – it might also be interesting to include artists as well!

It would be useful to perform the same analysis on album tracks but this involves meeting the challenge of assessing the contributions of multiple tracks with possibly different loudness – without imposing a heavy burden on a listeners, this would probably have rely on actual loudness (meter) measurements rather than an assessment panel.

As indicated above, there is scope for investigating the impact of different loudness profiles as opposed to simple averages & maxima and a particularly intriguing (but commercially sensitive) area for exploration is that of the interactions between sales & radio/TV airplay – this would require a time based analysis of the correlations between sales & TV/radio airplay in order to identify which are the leading & lagging factors.

As suggested by Robin Millar, it would also be highly relevant to measure the loudness of radio broadcasts of CDs which have varying degrees of compression to investigate the impact of broadcast processing, particularly compression.

From the background research discussed earlier, the researcher suggests that loudness may have become an additional factor in music listening due to the increased personal listening of music in noisy environments (traffic, transport etc), and that, in the absence of the sort of AVC implemented by most current in-car audio systems (based on car speed), compression might increase audibility in these environments avoiding the need to adjust the volume as the background noise level changes – this could be considered a form of laziness but as Bull (referenced earlier) indicates, since personal listening (via headphones or earpieces) is sometimes a way of blocking out noise (hence the often high volume levels), the researcher would argue that compression may contribute to audibility by increasing loudness and thereby raising the minimum level above the external noise – the researcher’s personal experience has established that very high listening levels are necessary with...
most headphones or earpieces to block out nearby conversations, announcements etc when travelling which raises the associated issue of the degree of sound insulation provided by personal listening devices between the ears and the external environment – if this were better, then it would be possible to listen at lower loudness levels with the blessing of fellow passengers!

However, there is ample medical research evidence (see bibliography) that exposure to high volume levels can lead to both temporary & permanent deafness – although most of this relates to ‘open’ listening in club or concert environments (and by extrapolation to studio monitoring levels) and to average loudness levels (expressed in dB), the researcher suggests that this may apply to personal listening and be influenced by compression – it could be interesting, though possibly difficult, to investigate whether deafness due to exposure to high personal listening levels is influenced by the degree of compression and the loudness profile (as discussed earlier) and whether there is any difference in damage caused by personal listening or ‘open’ listening at the same loudness level – this might reveal whether hearing damage is related to the ‘tiring’ effect due to the lack of respite in constantly loud or heavily compressed music.

This possible connection between compression and hearing damage raises some interesting legal considerations – loudness levels in clubs & concerts is controlled by laws and, presumably, customers have no recourse in the event of damage if the venues operate within the law – however, personal listening has no such controls as far the researcher is aware – ‘open’ listening in a private environment could be a hazard but would require very high power amplification and/or close proximity to the speakers – dangerous loudness levels from headphones or earpieces is easily achieved and is not subject to any legislation on the part of the equipment manufacturers or, more interestingly in the context of this project, the music providers even if the equipment was volume limited, the maximum loudness would be a function of that of the source music – it could be argued that, in the event of hearing damage caused by personal listening, there could be considered to be a legal liability on the part of the equipment manufacturers or, more interestingly in the context of this project, the music providers – even if the equipment was volume limited, the maximum loudness would be a function of that of the source music – it could be argued that, in the event of hearing damage caused by personal listening, there could be considered to be a legal liability on the part of the equipment manufacturers.

10.4 Coda

The music industry, particularly recorded music, is undergoing a period of rapid change, mostly attributed to the technological revolution impacting the recording & distribution of popular music but consequently due to social changes in the way music is produced & consumed – unless & until there are significant changes in this situation, recorded music is not going to be the money spinner that it has been and many participants are not going to survive.

The obsession with compression is one of many phenomena in the industry that has developed over time in response to commercial pressures but without being based on any sound foundations – with lower returns from recording music, businesses (that want to survive) will not be able to afford to take the same level of commercial risk as before – this raises some interesting challenges for artists, particularly new entrants, but whoever undertakes the recording would be well advised to ensure that the technical & commercial aspects of their output follow professional advice based on sound research leaving them to concentrate on artistic matters.

From this research, the obsession with compression appears to be at best unjustified and with possible medical & consequential legal exposures – this should be of interest, if not concern, to personal music player manufacturers as well as music providers - will the obsessed take note and de-escalate the loudness war? Perhaps it will take either legal action from a deafened consumer or music loudness legislation to restore the peace!
11. Reference List

As explained above, despite consulting various other relevant academic institutions, the researcher did not discover any directly related research or studies – consequently, the majority of this project involved primary research.

Additionally, and perhaps inevitably, since this is a topical, though not totally new, area of interest within the music community, most specific references above are to events that the researcher attended during the course of this project or to journal/online articles.

Also, though not strictly acceptable as a reference, the following Wikipedia entry is referred to above and included here for completeness - Wikipedia, Online, 24/11/2008, Available: http://en.wikipedia.org/wiki/Loudness_war


Ford, T 1993, Advanced Audio Production Techniques, Focal, Newton MA


Lund T 2006, ‘Control of Loudness in Digital TV’, Online, Available,  

http://www.youtube.com/watch?v=3Gmex_4hreQ&feature=iv&annotation_id=event_654875

‘Metallica Death Magnetic - CD vs. "Guitar Hero" comparison’, Online, 18/9/2008, Available:  
http://www.youtube.com/watch?v=DRyIACDCc1

Millard, E 24/6/2004, ‘Dr. Michael Bull on the iPod-as-Icon’, Online, Available:  
http://www.macnewsworld.com/story/34703.html

‘MPG News - The UK Music Producers Guild Turns Up The Volume On The Loudness Debate’,  


‘The Death of Dynamic Range: A Chronology of the Compact Disc Loudness Wars’, Online,  


http://news.bbc.co.uk/1/hi/technology/3542391.stm

http://uk.youtube.com/watch?v=wfBU8mG4csY&feature=related

12. Bibliography

As explained above, as there is little published information directly relevant to this research, this bibliography consists primarily of background reading primarily relating to related psychoacoustic or social phenomena.

12.1 Books


12.2 Journal Articles


Sterne, J 2006, ‘The mp3 as cultural artifact’, *New Media & Society*, Volume 8, Number 5 (October 2006), pp 825-842


12.3 Internet


13. Discography

See section 15.3 for the details of the CD singles used in this project.
14. Acknowledgements

Kim Bayley, Director General, Entertainment Retailers Association (ERA) for her review of the draft and constructive criticism

Mike Cave of Loft Mastering for his compilation of the composite CD.

Mike Collins, Producer for his review of the draft and detailed constructive feedback.

Duncan Cowell of Sound Mastering for

Prof. Nick Cook at CHARM for his advice and referral to reviewers.

Maureen Droney & Sonya Shearin of the Recording Academy, Producer & Engineer wing for their assistance with coordinating the US listening panel.

Andy East, Programme Leader, London College of Music for his supervision & support.

Penny Ganz of P Ganz & Co for her advice about copyright concerning the composite CD and its duplicates.

Dr. Chris Kennett, University of Westminster for her review of the draft and constructive comments.

Prof. Tia de Nora, Department of Sociology & Philosophy, HuSS, Exeter University for her reference information

Eric Nicoli (ex. Chairman of EMI) for his invaluable advice & guidance.

Andy Page of DK Technologies for the loan of their loudness meter.

Justin Paterson, Course Leader, TVU for his advice & support.

Tony Platt of Platinum Tones Productions for his support on behalf of the MPG including assembling the UK listening panel and review of the draft.

Mike Richter for his hosting useful background information on his website.

Sue Sillitoe of the MPG and Richard Kelley of DK Technologies for arranging the loan of the loudness meter.

Ray Staff for his kind offer of assistance with compilation of the composite CD.

Derek Varnals of BPI for his comments on the draft and kind offer to discuss further.

Kate Whitmarsh of Upper11 Records for her kindness in discussing her research.

14.1 The listening panel

My sincere thanks to the 36 professional producers & engineers who gave me their valuable time to listen to the tracks and complete the questionnaire.

Dave Aston of the Digital Audio Company

Haydn Bendall

Ned Bigham of Ocean Bloem Productions

Michael Bishop of Telarc International
Paul Blakemore of the Telarc division of the Concord Music Group
Mike Brown of Original Sound
Phill Brown of Bedrock
Luke Buttery of the Way Studio
Eric Chun of Creative Music Services, NFE Records
Patrick Collins of Collins & Associates
John Cuniberti of JohnCuniberti.com
Richard Digby Smith
Jeff Gazdacko of Telarc International
Mick Glossop
Garret Haines of Treelady Studios
Phil Harding of P.J.Music
David Harries of Audio Design Solutions
Stephen Hart of Bay Area Sound Studios
Greg Haver of Stephen Budd Management
Chris Hildebrand of Treehouse Sessions
Mike Howlett of Embryonix
Bill Hume of the Zone
Wes Maebe of GHQ
Bill McKinney of Telarc International
Jim McTigue of Impulsive Audio Consulting
Robin Millar of Arts Media
Hank Neuberger of Springboard Productions
Mike Nielsen of Air Management
Gerry O’Riordan of Spatial Audio
Tony Platt of Platinum Tones Productions
Mark Rose of Deep Recording Studios
Andrew Scheps
Tim Vine-Lott of Air Studios
Kamran V of Cykik
David Ward of James
Pip Williams of TVU
15 Support Documentation
In order to restrict the amount of printing required, much of this support documentation is provided in soft copy on the attached CD (see section 15.2 below).
### 15.1 Index of Composite Audio CD

This data was extracted from Music Week charts – the researcher cannot vouch for its accuracy.

<table>
<thead>
<tr>
<th>track #</th>
<th>title</th>
<th>artist</th>
<th>publisher</th>
<th>writer</th>
<th>label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 minutes</td>
<td>madonna</td>
<td>Warner - Chappel/ Universal/ Z/ Webo Girl/ Tenmen/ Virgin/ Imagem</td>
<td>Timberlake/ Mosley/ Hills/ Madonna</td>
<td>warner</td>
</tr>
<tr>
<td>2</td>
<td>always where I need to be</td>
<td>the kooks</td>
<td>Sony ATV/ Imagem</td>
<td>Pritchard</td>
<td>virgin</td>
</tr>
<tr>
<td>3</td>
<td>american boy</td>
<td>estelle</td>
<td>Chrysalis/ Carlin/ Catalyst/ Cherry Lane/ EMI</td>
<td>Lopez/ Speir/ Harris/ Adams/ Estelle/ West</td>
<td>atlantic</td>
</tr>
<tr>
<td>4</td>
<td>bye bye</td>
<td>mariah carey</td>
<td>Universal/ Sony ATV/ EMI</td>
<td>Carey/ Hermansen/ Austin/ Eriksen</td>
<td>def jam</td>
</tr>
<tr>
<td>5</td>
<td>call the shots</td>
<td>girls aloud</td>
<td>Warner Chappell</td>
<td>Cooper/Higgins/Powell/Sommerville/Cowling</td>
<td>fascination</td>
</tr>
<tr>
<td>6</td>
<td>church</td>
<td>t-pain</td>
<td>EMI/ Sony ATV/ Imagem</td>
<td>Najim</td>
<td>jive</td>
</tr>
<tr>
<td>7</td>
<td>closer</td>
<td>ne-y</td>
<td>Mute/ Warner Chappell/ Sony ATV/ CC</td>
<td>Masterson/ Grankvist/ Ronald/ Craig/ Sullivan</td>
<td>def jam</td>
</tr>
<tr>
<td>8</td>
<td>daddy o</td>
<td>the wide boys</td>
<td>EMI/ Hero Music/ Notting Hill/ Universal</td>
<td>Mills/ Wiles/ Detnon/ Paul</td>
<td>AATW</td>
</tr>
<tr>
<td>9</td>
<td>Dance Wiv Me</td>
<td>Dizzee Rascal</td>
<td>Sony ATV/ Warner Chappell/ EMI</td>
<td>Jackson / Eriksen / Dabney / Her</td>
<td>Dirtee Stank</td>
</tr>
<tr>
<td>10</td>
<td>daylight</td>
<td>kelly rowland</td>
<td>EMI/ Abkco</td>
<td>Womack/ Payne</td>
<td>rca</td>
</tr>
<tr>
<td>11</td>
<td>don’t stop the music</td>
<td>rihanna</td>
<td>Sony ATV/ Warner Chappell/ EMI</td>
<td>Jackson / Eriksen / Dabney / Her</td>
<td>def jam</td>
</tr>
<tr>
<td>12</td>
<td>electric feel</td>
<td>MGMT</td>
<td>Universal</td>
<td>Goldwasser/ Vanwyngarden</td>
<td>columbia</td>
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<tr>
<td>13</td>
<td>elevator</td>
<td>flo rida</td>
<td>Sony ATV/ Warner Chappell</td>
<td>Mosley/ Lane/ Dillard</td>
<td>atlantic</td>
</tr>
<tr>
<td>14</td>
<td>give it 2 me</td>
<td>madonna</td>
<td>EMI/ CC</td>
<td>Williams/ Madonna</td>
<td>warner</td>
</tr>
<tr>
<td>15</td>
<td>happiness</td>
<td>goldfrapp</td>
<td>Warner Chappell</td>
<td>Goldfrapp/ Gregory</td>
<td>mute</td>
</tr>
<tr>
<td>16</td>
<td>heartbeat</td>
<td>scouting for girls</td>
<td>EMI</td>
<td>Stride</td>
<td>epic</td>
</tr>
<tr>
<td>17</td>
<td>let it go</td>
<td>brit &amp; alex</td>
<td>Feemstro/ Universal/ Z Tunes/</td>
<td>Feemster/ Pratt/ Mischke/ Arinos</td>
<td>interscope</td>
</tr>
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<td>Track</td>
<td>Artist</td>
<td>Song Title</td>
<td>Writer(s)</td>
<td>Label/Owner</td>
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<td>---------------------------------------------------------------------------</td>
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<tr>
<td>18</td>
<td>love like this</td>
<td>Natasha Bedingfield</td>
<td>Rayna Rinat/ Sony ATV/ Kobalt/ In - Genius/ CC/ EMI Tedder/ Watters/ Wilkins/ Biancianiello/ Love/ And</td>
<td>phonogenic</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>maybe</td>
<td>jay sean</td>
<td>2Point9/ CC Sampson/ Sean 2point9/jayded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>nine in the afternoon</td>
<td>panic in the disco</td>
<td>EMI/ Sweet Chin Panic At The Disco decaydance/fueled by ramen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Not Nineteen Forever</td>
<td>the courteeners</td>
<td>Universal/ Fray polydor/a&amp;m?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Now You're Gone</td>
<td>basshunter</td>
<td>Warner Chappell/ Collect/ Nick's Music Altberg/ Nabuurs hard2beat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>one day like this</td>
<td>elbow</td>
<td>Warner Chappell/ Salvation Elbow polydor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>rhythm is a dancer '08</td>
<td>snap!</td>
<td>Universal/ Warner Chappell Benites/ Garrett/ Austin logic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>take a bow</td>
<td>rihanna</td>
<td>EMI/ Sony ATV/ Imagem Smith/ Eriksen/ Hermansen def jam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>that's not my name</td>
<td>the ting tings</td>
<td>Playwrite/ Sony ATV/ Warner Chappell de Martino/ White sony/bmg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>touch my body</td>
<td>mariah carey</td>
<td>Universal/ Peermusic/ EMI Stewart def jam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>trippin' on you</td>
<td>cahill</td>
<td>EMI/ CC Brown/ D Ramsey/ R Ramsey AATW</td>
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<td></td>
</tr>
<tr>
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<td>umbrella</td>
<td>rihanna</td>
<td>EMI/ Peer/ Sony ATV Stewart/ Nash/ Harrell/ Carter def jam</td>
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<td></td>
</tr>
<tr>
<td>30</td>
<td>watch out</td>
<td>alex gaudino</td>
<td>Warner Chappell Underwood/ Johnstone/ Lee/ Moore/ Hamlin/ Carpenter/ Fre data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
15.2 Index of Data CD

15.2.1 Data Workbooks
These contain a mixture of source data transcribed from assessment questionnaires & Music Week charts and as measured by the DK loudness meter plus derived data & charts – the copyright in this data rests with the researcher (all rights reserved) and is not authorised to be copied or used without his written permission – it is included in this submission for the sole purpose of allowing the project supervisor (and his designates) to validate the analysis as part of assessing the dissertation.

15.2.1.1 database.xls
This contains the source data transcribed from the listening panel questionnaires (personal identification data has been removed), the summary chart data linked from the ‘mw data’ workbook, the summary loudness data transcribed from the ‘track n(x)’ workbooks and derived data & charts including correlations.

15.2.1.2 mw data.xls
This contains the source data transcribed from the Music Week charts and derived data & charts including summaries of the listening panel responses to each track.

15.2.1.3 track n.xls
These contain the loudness readings from the DK loudness meter for each track excerpt (n) and derived data.

15.2.1.4 track nx.xls
These contain the loudness readings from the DK loudness meter for each full track (n) and derived data.

15.2.2 Music Week Charts
These contain sales & radio/TV airplay data downloaded from the online journals (via Athens) – the copyrights remain with the owners as indicated – they are included here for completeness as a component of individual research – see the notes on radio & TV airplay charts for details of their coverage.

15.2.2.1 sales ddmmyy.xls
These contain the sales chart data by week for 2007 (journal dated ddmmyy) – the copyright rests with the Official UK Charts Company which supplies this data to Music Week.

15.2.2.2 sales wkn.xls
These contain the sales chart data by week for 2008 (week n) – the copyright rests with the Official UK Charts Company which supplies this data to Music Week.

15.2.2.3 radio ddmmyy.xls
These contain the radio airplay data by week for 2007 (journal dated ddmmyy) – the copyright rests with the Nielsen Music Control which supplies this data to Music Week.

15.2.2.4 radio wkn
These contain the radio airplay data by week for 2008 (week n) – the copyright rests with Nielsen Music Control which supplies this data to Music Week.

15.2.2.5 tv nnnnnn.xls
These contain the TV airplay data by week for 2007 (journal dated ddmmyy) – the copyright rests with the Nielsen Music Control which supplies this data to Music Week.

15.2.2.6 tv wkn
These contain the TV airplay data by week for 2008 (week n) – the copyright rests with Nielsen Music Control which supplies this data to Music Week.
15.2.3 Summary Presentation
Summary.ppt contains a short presentation summarising the project.

15.2.4 Dissertation
Dissertation.pdf contains this document which may not be copied or distributed without the express written permission of the author.

15.2.5 Third Party Feedback
The ‘feedback’ folder contains MHTML files of emails from those third parties who provided feedback – this is confidential and not for publication - it is only included here to facilitate assessment of this dissertation.
15.3 Assessment Panel Questionnaire

See next 3 pages
QUESTIONNAIRE

Thank you for participating in the ‘Obsession with Compression’ project to explore the relationships between various attributes of current popular music and its commercial success – your participation will be acknowledged in the resulting dissertation and any subsequent publication but no answers will be attributed to an individual other than your name and company/organisation.

This project complements current discussion fora in the UK within the MPG (‘Loudness Wars’) and the APRS (‘Dynamics Debate’)

PROJECT SUMMARY

This is the final project of an MPG (Music Producers’ Guild) student member’s Masters degree in Audio Technology at the London College of Music – it is an investigation into correlations between certain musical & technical aspects of contemporary ‘popular’ music and its commercial success – it will employ an in depth analysis of data of the following major categories and investigate any correlations between them (the subcategories are examples of possible data for investigation depending on their availability):

Musical (genre, BPM, key, time signature, length);
Technical (overall processing especially compression);
Commercial (chart positions, radio/TV airplay & playlists).

The technical evaluation is being conducted by a panel of experts from the music business including producers & engineers in the UK & USA who are being invited to listen to 30 excerpts from a random selection of recent CD singles (assembled onto a single composite CD via digital transfer without any processing) and to complete a short questionnaire about the qualities of each track – the results will be shared with all participating organisations.

INSTRUCTIONS

The composite CD contains 30 excerpts from recent CD single releases – you must listen to them directly using a CD player (do not rip or transfer them to another device) - listen to the tracks in sequence at your normal listening level & settings without adjusting any controls during the exercise - please listen to all of the tracks at one ‘sitting’ and record your answers to each question immediately after listening to each one – please do not take account of anything that you already know about the tracks nor anybody else’s views – it is your personal opinion that is requested.

If you have any difficulties in completing the questionnaire, please contact the researcher via email at the address below or call him on +44 78 02 24 83 26 between 0900 & 2100 GMT.

Please return your completed questionnaire as soon as possible but no later than 30th September preferably by soft copy via email to dave-viney@btconnect.com or, if this is not possible, in hard copy via the post to Dave Viney, 16 Hillcroft Crescent, London W5 2SQ, UK/GB – please retain a copy in case of queries.

*** IMPORTANT ***

The researcher has assembled the composite CD for non-commercial use and it is for research purposes only - copyright remains with the current owners - copying is prohibited.

The researcher gratefully acknowledges the assistance of Mike Cave of Loft Mastering (www.loftmastering.com) in assembling the composite CD which has been produced & duplicated by digital transfer to preserve the quality of the original tracks – please retain it in case of any queries and do not give it away!
QUESTIONS to be answered for each track on the following page

1) Have you heard it before?
   a) yes
   b) not sure
   c) no

2) Were you involved in its recording, production, marketing, distribution or sale?
   a) yes
   b) no

3) How would you classify its genre?
   a) pop
   b) rock/indie
   c) R&B/hiphop
   d) country/bluegrass
   e) latin
   f) dance/electro
   g) classical/jazz
   h) other (please specify)

4) What makes it distinctive/special/different?
   a) nothing
   b) structure/arrangement
   c) orchestration/instrumentation
   d) melody/tune
   e) lyrics/vocal
   f) other (please specify)

5) How would you rate the sound quality?
   a) pleasant to listen to
   b) unpleasant to listen to

6) How would you rate the overall sound quality versus other CDs?
   a) well below average
   b) below average
   c) average
   d) above average
   e) well above average

7) How does it sound compared to the other tracks on this CD?
   a) much louder
   b) slightly louder
   c) same
   d) slightly quieter
   e) much quieter

8) How would you assess its overall level of overall compression?
   a) far too much
   b) too much
   c) about right
   d) too little
   e) far too little
   f) not qualified to assess

9) How would you assess its overall level of overall processing (EQ etc)?
   a) far too much
   b) too much
   c) about right
   d) too little
   e) far too little
   f) not qualified to assess
For the following questions, please insert or select your answers (by deleting the others) between the square brackets

What is the ‘Disk number’ on the CD label [____]

What is your full name? [__________________________________________]

What is your age (for demographic analysis only) [___]

What is your gender [male female]

What is your primary profession [producer engineer A&R distributor plugger ‘consumer’]

What is the name of your company/organisation (for acknowledgements) [__________________________]

What is your email address or telephone number (for resolving any queries) [__________________________]

What best describes your listening environment [studio car home other (please specify)]

What best describes your CD player [professional consumer portable]

How did you listen to the CD [loudspeakers headphones earpieces]

Would you be prepared to discuss your views regarding compression with the researcher [yes no not qualified to discuss]

For each of the questions on the previous page, please insert the letter corresponding to your answer into the appropriate box for each track

**Note** the last 2 questions are directed only at those who are professionally qualified to assess the overall compression & processing of the tracks

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
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<tr>
<td>Track 1</td>
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15.4 Email from Duncan Cowell (edited)

This resulted from a ‘Mastering’ master class held by Duncan at TVU on 7/5/2008 – the researcher’s questions are in shown in **bold**.

‘**Given the need for different mastering actions to suit different media & listening environments (vinyl/CD + home/ car/ club/ radio/ iPod etc), do you get asked or offer to produce multiple masters?**

No, normally we do the CD master and the vinyl is cut from that. The cutting engineer will make any changes in EQ that s/he feels necessary - e.g. filtering off the bass at 40Hz. I'd like to do the coding for MP3 but record companies on the whole don’t seem to realise that there are different codecs out there and some of them sound rubbish! Also, as I said at the Masterclass, I've noticed lossy compression sounds substantially better when there are plenty of dynamics left in the music, so I'd really like that stage to be done post-EQ but pre-compression.

I have to say that I don't think there are "different mastering actions for different listening environments". The whole idea of a mastering studio is that it's a reference room, built to reproduce sound as accurately as possible rather than in a flattering way. Any subsequent anomalies will be that of the final listening environment - and as they're ALL different there's no way to adjust the mastering to suit all of them, so you have the mastering studio as a definitive room - and while no two mastering studios are the same, they all have certain design principles associated with them, and you tend to find quite different monitoring set-ups to that of recording studios too.

**If not, how do you optimise (or compromise) for different requirements?**

By only trying to do what's best for the sound. I find that uncontrolled very low bass (0 - 30Hz) can be distracting and use up energy unnecessarily so I tend to filter that off anyway, which kind of coincides with the roll-off required for vinyl and club. Radio squashes the gonads out of whatever you give them so I try not to hammer stuff in the first place as, conversely, a quieter master actually sounds louder on radio than a loud-but-heavily-compressed master. Most artists, unfortunately, just want their stuff as loud as possible. I despair...

**What is being done to use metadata in codecs (mp3, Dolby et al) to inform reproduction systems about mastering actions and so allow them to adapt to listening requirements?**

Nothing, as far as I'm aware. Dolby and DTS have pretty strict standards about level anyway. There's stuff like "MP3 Gain" (I think it's called) which is a bit of software that normalises (downwards) loud stuff to sit in a compilation with quiet stuff by taking an average amplitude reading, rating the loudness as a percentage, and adjusting the gain accordingly. I'd love to see one in every audio reproducing gadget available because then the "loudness war" would end as it would become completely futile - nothing would be louder than anything else. There's no "loudness war" in film because Dolby set the level standards - and if you don't stick to them, you can't use Dolby. When I demonstrate to people that their "loud" master is of inferior sonic quality to the "quiet" master (by means of level matching them and simply listening) they almost always agree and then go ahead and release the loud one anyway... Bob Katz's idea for a standard similar to Dolby's, along with metadata, can be found here: [http://www.digido.com/bob-katz/level-practices-part-2-includes-the-k-system.html](http://www.digido.com/bob-katz/level-practices-part-2-includes-the-k-system.html) He says it all much better than I can.
15.5 Extract from Copyright Law

This was provided by Penny Ganz of P Ganz & Co as background to her advice concerning labelling of the composite CD and its duplicates.

COPYRIGHT, TRADEMARKS & PATENTS CT 1988
search and private study
29.-(1) Fair dealing with a literary, dramatic, musical or artistic work for the purposes of research for a non-commercial purpose does not infringe any copyright in the work provided that it is accompanied by a sufficient acknowledgement. (IB) No acknowledgement is required in connection with fair dealing for the purposes mentioned in subsection (1) where this would be impossible for reasons of practicality or otherwise. (IC) Fair dealing with a literary, dramatic, musical or artistic. work for the purposes of private study does not infringe any copyright in the work. (2) Fair dealing with the typographical arrangement of a published edition for (a) in the case of a librarian, or a person acting on behalf of a librarian, he does anything which regulations under section 40 would not permit to be done under section 38 or 39 (articles or parts of published works: restriction on multiple copies of same material), or (b) in any other case, the person doing the copying knows or has reason to believe that it will result in copies of substantially the same material being provided to more than one person at substantially the same time and for substantially the same purpose. (4) It is not fair dealing (a) to convert a computer program expressed in a low level language into a version expressed in a higher level language, or (b) incidentally in the course of so converting the program, to copy it, (these being acts permitted if done in accordance with section 50B (decompilation)). (4A) It is not fair dealing to observe, study or test the functioning of a computer program in order to determine the ideas and principles which underlie any element of the program (these acts being permitted if done in accordance with section 50BA (observing, studying and testing)). (5) [...] Note: Subsection (4) was inserted by the Copyright (Computer Programs) Regulations 1992 (SI 19921323), with effect from January 1, 1993. For savings and transitional provisions, see regulation 12 of those Regulations. Subsection (1) was amended by, and subsections (1A) and (5) were inserted by the Copyright and Rights in Databases Regulations 1997 (SI 199713032), with effect from January 1, 1998. For savings and transitional proviral provisions, see sections 26 to 30 of those Regulations.

criticism, review and news reporting
30.- (1) Fair dealing with a work for the purpose of criticism or review, of that or another work or of a performance of a work, does not infringe any copyright in the work provided that it is accompanied by a sufficient acknowledgement. (1A) Fair dealing with a database for the purposes of research or private study does not infringe any copyright in the database provided that the source is indicated. (5) The doing of anything in relation to a database for the purposes of research for a commercial purpose is not fair dealing with the database.

The Obsession With Compression 74 © 2008 Dave Viney. All rights reserved.
(c) the rental or lending of copies of the work to the public;
(d) the performance, exhibition, playing or showing of the work in public;
(e) the communication to the public of the work,
but in determining generally for the purposes of that subsection whether a work
has been made available to the public no account shall be taken of any unauthorised
act.

(2) Fair dealing with a work (other than a photograph) for the purpose
of reporting current events does not infringe any copyright in the work provided
that (subject to subsection (3)) it is accompanied by a sufficient acknowledgement.
(3) No acknowledgement is required in connection with the reporting of current
events by means of a sound recording, [or broadcast where this would
be impossible for reasons of practicality or otherwise].

Note: The words in square brackets in subs.(l) and subs.(lA) were inserted and the
words in square brackets in subs.(3) substituted for the former words "broadcast or cable
programme" by the Copyright and Related Rights Regulations 2003 (SI 2003/12498),
reg.10 with effect from October 31,2003. For savings and transitional provisions, see Part IIf
3 of those Regulations.

The Broadcasting Act 1996. s.137(1) provides
(1) Any provision in an agreement is void in so far as it purports to prohibit or restrict
relevant dealing with a broadcast in any circumstance where by virtue of section
30(2) of the Copyright, Designs and Patents Act 1988 (fair dealing for the
purpose of reporting current events) copyright in the broadcast is not infringed.
This provision was brought into effect from October 1,1996 by virtue of the Broadcasting
Act 1996 (Commencement No. 1 and Transitional Provisions) Order 1996 (SI 1996/2120) and is printed as amended by the Copyright and Related Rights Regulations 2003

Incidental inclusion of copyright material
31.- (1) Copyright in a work is not infringed by its incidental inclusion in an
artistic work, sound recording, [or broadcast].
(2) Nor is the copyright infringed by the issue to the public of copies, or the
playing, showing [or communication to the public], of anything whose making
was, by virtue of subsection (l), not an infringement of the copyright.
(3) A musical work, words spoken or sung with music, or so much of a sound
recording or broadcast as includes a musical work or such words, shall not be
regarded as incidentally included in another work if it is deliberately included.

Note: The words in square brackets in subss.(l) and (3) were substituted for the former
15.6 Extract from Excel Help
This was obtained by virtue of having a licence for Microsoft Office 2007 – copyright is owned by Microsoft.

**CORREL function**

Returns the correlation coefficient of the array1 and array2 cell ranges. Use the correlation coefficient to determine the relationship between two properties. For example, you can examine the relationship between a location’s average temperature and the use of air conditioners.

**Syntax**

CORREL(array1, array2)

*Array1* is a cell range of values.

*Array2* is a second cell range of values.

**Remarks**

- If an array or reference argument contains text, logical values, or empty cells, those values are ignored; however, cells with the value zero are included.

- If array1 and array2 have a different number of data points, CORREL returns the #N/A error value.

- If either array1 or array2 is empty, or if s (the standard deviation) of their values equals zero, CORREL returns the #DIV/0! error value.

- The equation for the correlation coefficient is:

\[
\text{Correl}(X, Y) = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}
\]

where \( x \) and \( y \) are the sample means AVERAGE(array1) and AVERAGE(array2).

**Example**

The example may be easier to understand if you copy it to a blank worksheet.

[How to copy an example]
NOTE Do not select the row or column headers.

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Selecting an example from Help

3. Press CTRL+C.

4. In the worksheet, select cell A1, and press CTRL+V.

5. To switch between viewing the results and viewing the formulas that return the results, press CTRL+` (grave accent), or on the **Formulas** tab, in the **Formula Auditing** group, click the **Show Formulas** button.

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<tr>
<th>Formula</th>
<th>Description (Result)</th>
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<tr>
<td>=CORREL(A2:A6,B2:B6)</td>
<td>Correlation coefficient of the two data sets above (0.997054)</td>
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